Volume 3: Engineering, Construction and Operations

ENBRIDGE NORTHERN GATEWAY PROJECT

Sec. 52 Application

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1 Introduction

1.1 Purpose

This document is part of the Application to the National Energy Board (NEB) by Northern Gateway Pipelines Inc. for approval to construct and operate the Enbridge Northern Gateway Project (the Project). It describes the conceptual design of the pipelines and related facilities that comprise the Project together with the associated construction and the operation activities.

1.2 Project Overview

The Project will serve two purposes:

- to transport oil from Bruderheim, Alberta to Kitimat, British Columbia, where it will be loaded onto tankers for delivery to markets
- to unload condensate from tankers at Kitimat and transport it to Bruderheim for delivery to Alberta markets (for the purposes of this Application, condensate is defined as a low volatility hydrocarbon equivalent to diluent)

It will be designed for an average annual throughput of 83,400 m^3/d (525,000 bbl/d) of oil and 30,700 m^3/d (193,000 bbl/d) of condensate, and will consist of the following major facilities:

- an oil pipeline, 914 mm outside diameter (OD) (NPS 36), approximately 1,172 km long extending from the Bruderheim Station to the Kitimat Terminal
- a condensate pipeline, 508 mm OD (NPS 20), approximately 1,172 km long, in the same right-of-way (RoW) as the oil pipeline, extending from the Kitimat Terminal to the Bruderheim Station
- two tunnels, approximately 6.5 km and 6.6 km long, to route the oil and condensate pipelines through the mountains between the Clore River and Hoult Creek valleys
- the Bruderheim Station (NE 4-56-21 W4), near Bruderheim, will comprise an initiating oil pump station and condensate receiving facilities
- intermediate pump stations at eight locations along the pipeline route
  - six of these locations will have pump stations for both the oil pipeline and the condensate pipeline
  - two of these locations will have a pump station for only the condensate pipeline
- the Kitimat Terminal (UTM Zone 9 Easting 518436, Northing 5977703), near Kitimat, will comprise the following:
  - a tank terminal including oil tanks, condensate tanks and associated infrastructure
  - a marine terminal including two tanker berths and one utility berth
  - an initiating condensate pump station
  - oil receiving facilities

For an overview map showing the locations of these project facilities, see Appendix A, Figure A-1.

The shippers on the system will choose how they access the pipelines. That choice may involve Enbridge Pipelines Inc. (Enbridge) facilities, the Stonefell Terminal (adjacent to the Bruderheim Station), another party's facilities or a direct connection to upstream pipeline facilities. The choices and decisions relating to the connection facilities will be made during detailed engineering.

1.3 Project Schedule

Table 1-1 summarizes the key milestones for the Project.

Table 1-1 Key Project Milestones

Item	Project Milestone	Start Date	Completion Date
1	NEB Application Submission	–	Q2, 2010
2	Detailed Engineering	Q1, 2011	Q1, 2015
3	Joint Review Panel Hearing	Q1, 2011	Q2, 2011
4	Governor-in-Council (GIC) Decision		Q2, 2012
5	Commercial Sanction	Q2, 2012	Q3, 2012
6	Procurement of Major Material and Equipment	Q3, 2012	Q3, 2016
7	Kitimat Terminal Construction	Q2, 2013	Q3, 2017[a]
8	Tunnel Construction	Q2, 2013	Q4, 2016
9	Oil and Condensate Pipeline Construction	Q4, 2013	Q4, 2016
10	Pump Station Construction	Q3, 2014	Q4, 2016
11	Leave-to-Open and Commissioning	Q3, 2016	Q4, 2016
12	Project In-service		Q4, 2016[b]

NOTES:
[a] A limited number of tanks will see construction extend beyond the in-service date to Q3, 2017.
[b] Q4, 2016 is the earliest in-service date.

1.4 Regulations, Codes and Standards

The pipelines, pump stations, Kitimat Terminal and associated facilities will be designed, constructed and operated in accordance with applicable regulations and the industry codes and standards that these regulations reference.

As the Project falls under the jurisdiction of the NEB, it will be designed, constructed and operated to comply with the latest NEB regulations, including the Onshore Pipeline Regulations, 1999 (OPR-99), which incorporate, by reference, the Canadian Standards Association (CSA) Z662-07, Oil and Gas Pipeline Systems. These standards in turn reference other standards and publications, which will be followed as appropriate in the design. The pipelines and facilities will be designed and built in accordance with Enbridge's Engineering Standards and Construction Specifications.

For a list of the applicable codes and standards, see Appendix B, Tables B-1 and B-2. Table B-1 lists the codes and standards that will be used in addition to CSA Z662-07. The Canadian codes will take precedence. However, in the absence of applicable Canadian codes, international codes may be used. Table B-2 identifies Enbridge Engineering Standards and Specifications that will apply to the Project.

1.5 NEB Concordance Table

See Appendix B, Table B-3 for the concordance table for this volume.

1.6 Quality Management

1.6.1 Design

As outlined in Section 1.4, the Project will be designed, constructed and operated to meet or exceed applicable regulations, codes and standards including OPR-99, CSA Z662-07, and Enbridge's engineering standards, specifications and manuals. The Enbridge standards, specifications and manuals meet or exceed the OPR-99 regulations.

Northern Gateway Limited Partnership (Northern Gateway), as builder and operator of the Project, will also follow Enbridge's Quality Assurance and Quality Control (QA/QC) program to ensure the pipelines and facilities are designed, constructed and operated in accordance with the OPR-99 and other applicable environmental, regulatory and corporate standards and guidelines.

1.6.2 Materials

Procured materials and equipment will comply with applicable codes and standards, including Enbridge's engineering equipment specifications and design standards. Material specifications will be developed for material and equipment not covered by existing Enbridge specifications.

1.6.3 Construction and Commissioning

Consistent with the OPR-99, a construction safety manual will be developed and implemented for the Project. This safety manual will incorporate the Enbridge Major Projects Health and Safety Management system and will be augmented by the Enbridge Construction Safety Manual. This manual will also include construction security and public safety considerations. A copy of this manual will be submitted to the NEB before project construction begins.

Enbridge's construction specifications for pipeline and facilities will be supplemented with additional specifications where necessary.

A joining program, which includes welding procedures and non-destructive examination (NDE) inspection specifications, will be developed consistent with the OPR-99.

Refer to Volume 7A for the Construction Environmental Protection and Management Plan (EPMP). A detailed Construction EPMP will be submitted before construction begins.

A commissioning plan for the Project will also be prepared and implemented.

1.6.4 Quality Audits

Periodic internal audits will be conducted for all aspects of the Project. The prime objective of the audits will be to document compliance. Identified deficiencies will be documented for resolution and follow-up.

1.6.5 Change Management

Enbridge's change management procedure for engineering design, construction and material specifications will be in effect for the Project.

2 Alternative Means to Construct the Project

2.1 General

Northern Gateway is proposing to construct and operate an oil and condensate pipeline between two end points, a station near Edmonton, Alberta and a tank and marine terminal near Kitimat, British Columbia. Alternative locations were evaluated for the Edmonton area station, tank and marine terminal and pipeline route. Once the locations were selected, further revisions and refinements were made and the intermediate pump stations were located. Through this process, the pipeline route ("the applied for route") was established for the Project (see Appendix C, Figures C-1 to C-14). The pipeline route is contained within a pipeline study corridor that is approximately 1-km wide and 1,172-km long.

The following sections describe the alternatives that were considered and outline the rationale for selecting the current location of the proposed pipeline route, pump stations and the Kitimat Terminal.

2.2 Edmonton Area Station and Terminal Locations

2.2.1 Edmonton Area Station Location

Two potential sites were considered near Edmonton, Alberta for the station. One site was near the existing Enbridge Edmonton Terminal on the east side of Edmonton, and the other site was near the Stonefell Terminal near Bruderheim (see Appendix D, Figure D-1).

The site near the Enbridge Stonefell Terminal, called the Bruderheim Station, was selected based on the following considerations:

- access to oil supply and condensate delivery markets
- proximity to existing industrial infrastructure
- availability of industrial land
- limited site congestion
- constructability, including effect on existing operations during construction
- avoidance of constraints associated with the existing Edmonton Transportation/Utility Corridor
- reduced the potential for land and resource use conflicts
- access to potential pipeline corridors to the west

2.2.2 Kitimat Terminal Location

Four potential sites were primarily considered for the Kitimat Terminal (see Appendix D, Figure D-2). Three of the sites are in an existing Kitimat industrial complex. Sites 1 and 2 are adjacent to the Rio Tinto Alcan site, and Site 3 is 4 km northwest of Kitimat. Site 4, the Kitimat Terminal site, is approximately 2 km south of the industrial complex in an area that the District of Kitimat has zoned for future industrial development.

Potential sites at Emsley Cove and Bish Cove were also considered but were not selected because of the incremental pipeline length and associated impacts and costs to reach these more southerly sites, the increased access and land constraints associated with these sites, or because other proposed projects were considering these locations.

Potential sites on the eastern shoreline of Kitimat Arm were also considered but were not selected to avoid established communities (e.g., Kitamaat Village) and land zoned for recreational use.

The location for the Kitimat Terminal was selected based on the following criteria:

- suitability of the location for the facilities (e.g., tanks and tanker berths)
- proximity to existing infrastructure
- minimal pipeline lengths
- suitable road access
- limited effects on watercourses, waterbodies, marine and aquatic vegetation and habitat, and important fish areas
- limited effects on terrestrial vegetation and wildlife habitat
- limited potential adverse effects on communities, landowners, land users and Aboriginal groups
- limited potential effect of shoreline oiling
- avoidance of parks and recreation areas (e.g. protected areas, marine parks, ecological reserves)

Sites 1 and 2, adjacent to the Rio Tinto Alcan site, are overlaid with thick overburden materials, some of which are compressible and could settle under load. These sites are zoned for industrial use. They are located on disturbed lands with limited value as habitat for sensitive wildlife; however, they are adjacent to fish-bearing streams and are closer to Kitimat residential areas. For these sites, the marine berth would be located a long distance from the tank terminal, thereby creating the need for extended linear infrastructure to link the tank terminal with the marine terminal.

Subsurface information was not available for Site 3. However, examination of aerial photographs indicate that bedrock is at, or near, ground surface over much of the area. The topography and subsurface conditions appear to be similar to those at the Kitimat Terminal site. However, a greater volume of rock would have to be excavated to develop Site 3 than the Kitimat Terminal site. Site 3 is zoned for industrial use; however, part of this site footprint extends into a floodplain and is zoned for recreation. This site is close to residential areas in Kitimat and is adjacent to disturbed sites with limited value as habitat for sensitive wildlife; but, it is adjacent to fish-bearing streams. The associated marine berth location for Site 3 is a site near the existing Eurocan Pulp & Paper Co. berth. It was determined that the berth site is underlain by marine clays and may be prone to settlement. For this site, the marine berth would be located a long distance away from the tank terminal, thereby creating the need for extended linear infrastructure to link the tank terminal with the marine terminal.

The Kitimat Terminal site is almost exclusively underlain by bedrock with minimal overburden. The Kitimat Terminal site is zoned for industrial development by the District of Kitimat. As a result of previous forestry activities, approximately 25% to 30% of the forest cover on the site has been disturbed or removed. The site does contain culturally modified trees indicative of past use for traditional purposes. The site does not overlap any designated recreational areas, but is near Bish Cove, which is used informally by residents of Kitimat for recreation. The site contains a small watercourse with marginal aquatic habitat but is unlikely to support salmon or other harvested fish species. The Kitimat Terminal site will not directly affect any known spawning areas, concentration areas for marine birds, protected areas or designated reserve lands. As a result of the predominantly rocky shoreline, this site will be less sensitive in the unlikely event of an accidental release of hydrocarbons. This site needs the least amount of extended linear infrastructure to link the tank terminal with the marine berth.

The proposed location for the Kitimat Terminal offers the following advantages in comparison with the other proposed sites:

- The wide channel provides safe manoeuvring room for berthing and unberthing operations.
- The harbour area near the berths provides a natural turning basin diameter of greater than 2,000 m, which is more than adequate for the vessels expected to use the terminal.
- The shoreline at the site provides a relatively unrestricted approach, and the berths can be designed so that vessels are aligned with the prevailing winds and currents during final approach and while moored at the berths.
- The seabed at this location slopes steeply downward from the shoreline so that deep draught, very large crude carrier (VLCC) class tankers can approach the berths.
- The land-based terminal facilities will be near the tanker berths.
- The land on the site rises about 180 m above the shoreline, which enables gravity loading of the oil tankers.
- Suitable foundation conditions are present for tanks and other major structures. Notably, the proposed site has bedrock at a shallow depth that will provide suitable support for the Terminal equipment with minimal foundation depth penetration while generating smaller volumes of disposal material. These conditions will also limit any potential issues associated with potential seismic activity.
- This site already has a large area logged. Further, the existing cut blocks are in the area of the proposed terminal, thereby reducing the amount of logging needed to prepare the site.
- The elevation of the selected site is such that the in-situ civil materials (rock, earth, clays, etc.) are suitable for re-use on the site for the terminal construction, thereby reducing disposal volumes and the volume of materials to be shipped into the site.
- The site is located away from designated reserve lands, spawning rivers, marine spawning areas, shore bird concentrations, and sensitive shorelines.

2.3 Pipeline Route

2.3.1 General

Northern Gateway considered various alternatives for the pipeline route during the preliminary design stage (see Appendix D, Figure D-3). Each alternative was reviewed by a team of engineering, geotechnical, construction and environmental specialists using available mapping, published information and visual reconnaissance of the various potential routes coupled with previous construction experience in many of the areas.

The initial pipeline route (see Appendix D, Figure D-3) was selected based on the following criteria:

- minimal pipeline length
- avoidance of parks, protected areas, wildlife areas, archaeological or heritage sites and other environmentally sensitive areas, where practical
- avoidance, where possible, of terrain subject to geotechnical issues such as unstable slopes
- limited potential adverse effects on communities, landowners, land users, Aboriginal groups, environmental and culturally sensitive areas
- provision of a safe and reliable route for pipeline construction and operations
- provision of suitable locations for watercourse, highway, road, rail and utility crossings
- provision of common locations for the intermediate oil and condensate pump stations and valve sites
- reduced lifecycle costs

See Sections 2.3.2 and 2.3.3 for further information that supports the selected pipeline route.

2.3.2 Eastern Route Segment Alternatives

The eastern segment of the initial pipeline route starts at the Bruderheim Station and runs northwest to a location about 50 km south of Grande Prairie and then southwest to Fort St. James (see Appendix D, Figure D-3). A more southerly pipeline route segment, Alternative A, was also considered. Alternative A also started near Bruderheim and then ran west to a point about 20 km north of Grand Cache, Alberta and then west where it joined the initial pipeline route segment near Ft. St. James. The initial pipeline route was selected for the following primary reasons:

- It follows existing rights-of-way for several transmission pipelines between Edmonton and Grande Prairie, in particular, the Alliance Pipeline system and the TransCanada Pipeline (TransCanada) Alberta System (formerly owned by NOVA Gas Transmission Ltd.).
- Road access for construction and maintenance equipment is substantially better along the more northerly initial pipeline route, as compared with Alternative A.
- It avoids the Narraway River valley, which straddles the Alberta and British Columbia boundary and presents significant geotechnical difficulties because of the presence of numerous incised streams that have unstable valley slopes.

- It avoids crossing the Kakwa Wildland Provincial Park in Alberta and the Kakwa Provincial Park and Protected Area in British Columbia.
- It avoids crossing three watercourses in western Alberta (Bolton, Beaverdam and Lynx Creeks) which are designated as Class A streams.

2.3.3 Western Route Segment Alternatives

The western segment of the initial pipeline route runs west of Fort St. James near to Burns Lake and then west along the Morice River valley to the upper Clore River valley (on the east side of Nimbus Mountain in the Coast Mountain Range) (see Appendix D, Figure D-3). It then crosses into the upper Kitimat River valley and follows the valley, first west and then south along the west side of the valley to the Kitimat Terminal.

Four alternative pipeline route segments (Alternatives B to E) and various combinations of these segments were considered before the initial pipeline route segment between Fort St. James and Kitimat was selected (see Appendix D, Figure D-3). The initial pipeline route was selected because the route:

- avoids crossing the recently designated Sutherland River Park and Protected Area located west of Fort St. James at the south end of Babine Lake
- avoids a long, challenging crossing of the lower Clore River
- is significantly shorter than the more northerly alternatives (i.e., Alternative B, C or D)
- runs along the west side of the lower Kitimat River valley and therefore avoids extensive areas on the east side of the valley that are underlain by sensitive marine clays that are prone to slope failure
- avoids crossing the Kitimat River
- avoids crossing the Tazdli Wyiez Bin/Burnie-Shea Provincial Park

2.4 Pipeline Route Revisions

2.4.1 General

The initial pipeline route was revised at specific locations as engineering and environmental studies and consultation progressed to establish the pipeline route. The primary criteria used to identify and select these revisions were as follows:

- reduce the pipeline length
- avoid parks, protected areas, wildlife areas, archaeological and heritage sites and other environmentally sensitive areas, where practical
- reduce potential adverse environmental effects on fish, wildlife and other environmentally sensitive species
- limit tree clearing and other potential disturbances by following existing linear disturbed areas where practical

- limit potential adverse effects on communities and land and resource users
- reduce the potential for land and resource use conflicts
- accommodate suggestions and concerns raised by landowners, the public, participating Aboriginal groups and the regulatory agencies, where practical
- confirm that a viable alternative crossing method is available near watercourse crossings where horizontal directional drilling (HDD) is the proposed crossing method
- avoid or limit exposure of the pipelines and associated facilities to geotechnical issues such as unstable slopes, rock falls and avalanches
- limit the volume of earthworks to prepare the RoW for pipeline construction

Substantial revisions were made to the initial pipeline route at 17 locations (see Sections 2.4.2 to 2.4.18 and Appendix D, Figures D-4 to D-13).

2.4.2 Bruderheim to Gibbons (KP 0 to KP 20)

The initial pipeline route was revised to address landowner and stakeholder input and project technical requirements (see Appendix D, Figure D-4). These revisions included:

- accommodating the needs for existing and proposed development on the east side of the North Saskatchewan River by Shell Canada Ltd. (Shell Canada owns several parcels of land in this area)
- accommodating a revised tie-in location to the Bruderheim Station
- establishing a suitable crossing location of the North Saskatchewan River
- maintaining an acceptable offset on the south side of Highway 643 immediately west of the North Saskatchewan River to allow for future development of land immediately adjacent to the highway
- establishing a route in the area north of Gibbons that is acceptable to the majority of affected landowners

2.4.3 Athabasca River Crossing (KP 186 to KP 200)

The initial pipeline route was revised to relocate the Athabasca River crossing (see Appendix D, Figure D-5). Geotechnical investigations indicated that a conventional trenched crossing would be very difficult at the initial crossing location and that an HDD crossing was unlikely to be successful. Additionally, there was a deep-seated landslide present on the north valley slope at the initial crossing location.

Landslides are present on the north valley slope of the Athabasca River at most locations along this reach of the river. However, a short section of stable valley slope was found at the current crossing location. Preliminary investigations conducted at this location indicate that it is suitable for a trenched crossing. The feasibility of an HDD crossing at this location will be evaluated during detailed engineering.

2.4.4 Chickadee Creek Crossing (KP 215 to KP 220)

The initial pipeline route was revised to relocate the Chickadee Creek crossing (see Appendix D, Figure D-5). Geotechnical investigations indicated the initial crossing location was unsuitable because of unstable valley slopes. Preliminary investigations conducted at the current crossing location indicate that the location is suitable for a trenched crossing. The pipeline route also avoids crossing several existing pipelines.

2.4.5 Alexander No. 134A (Fox Creek) Indian Reserve (KP 245 to KP 260)

The initial pipeline route was revised to accommodate future plans of the Alexander First Nation for land development (see Appendix D, Figure D-5). The Iosegun River crossing was also relocated to improve constructability.

2.4.6 Fox Creek to Smoky River (KP 310 to KP 415)

The initial pipeline route was revised to relocate the Simonette River crossing and to address issues raised by Alberta Sustainable Resources Development (ASRD) (see Appendix D, Figure D-6). This segment of the initial pipeline route provided the shortest route through the Fox Creek to Smoky River area. However, geotechnical investigations indicated the initial crossing location was unsuitable because of unstable valley slopes. Additionally, this segment of the initial pipeline route was not favoured by Alberta Sustainable Resources Development because of the lack of existing linear infrastructure and associated clearing that could be paralleled, compared with the two alternative segments described below.

A northerly alternative segment was considered. This segment followed the right-of-way of TransCanada's Alberta System and is the longest route through the area. In addition, the south valley slopes of the Simonette River on or near the TransCanada pipeline right-of-way are unstable and have been subject to monitoring and remediation.

The pipeline route follows the Alliance Pipeline right-of-way from KP 310 to KP 415 and provides good construction access. The valley slopes of the major watercourse crossings along the route, including Deep Valley Creek, the Simonette River and the Latornell River, appear suitable for conventional trenched crossing construction. The pipeline route also parallels existing linear infrastructure to the extent practical.

2.4.7 Smoky River Crossing (KP 415 to KP 475)

The initial pipeline route was revised to relocate the Smoky River crossing and to address issues raised by ASRD (see Appendix D, Figure D-7). Geotechnical investigations conducted at the initial crossing location of the Smoky River indicated that the location was unsuitable because of the presence of deep-seated landslides on the east valley slopes. Additionally, Alberta Sustainable Resources Development did not favour the initial pipeline route because it did not parallel a significant length of existing linear infrastructure.

Preliminary field investigations indicate that geotechnical conditions at the current crossing location of the Smoky River are substantially better than those encountered at the initial crossing location and appear suitable for a trenched crossing. Further geotechnical investigations to confirm subsurface conditions will

be conducted during detailed engineering. The pipeline route is also preferred by Alberta Sustainable Resources Development because it parallels a significant length of existing linear infrastructure compared with the initial pipeline route.

2.4.8 Wapiti River Crossing (KP 475 to KP 520)

The initial pipeline route was revised to relocate the Wapiti River crossing (see Appendix D, Figure D-8). Geotechnical investigations indicated the initial crossing location was unsuitable because of extensive instability on the east slope of the river valley. Preliminary field investigations indicate that geotechnical conditions at the current crossing location are substantially better and appear suitable for a trenched crossing. Further geotechnical investigations to confirm subsurface conditions will be conducted during detailed engineering.

2.4.9 South Redwillow River Crossing (KP 530 to KP 535)

The initial pipeline route was revised to relocate the South Redwillow River crossing (see Appendix D, Figure D-8). A wide wetland and deep channel at the initial crossing location would have made it very difficult to construct an isolated crossing. The river channel at the current crossing location is relatively shallow and more suitable for construction of an effective isolated crossing with reduced potential environmental effects.

2.4.10 Missinka River Tributary (KP 634 to KP 640)

The initial pipeline route was revised to improve constructability in the Missinka River Tributary area (see Appendix D, Figure D-9). The initial pipeline route ran along the north side of a high ridge that separates the Missinka River from one of its tributaries. Field investigations conducted in this area found that this segment of the pipeline route could be shortened and the pipeline elevation reduced by about 150 m by moving the segment north, near the bottom of the tributary valley.

2.4.11 Parsnip River Crossing (KP 664 to KP 681)

The initial pipeline route was revised to relocate the Parsnip River crossing (see Appendix D, Figure D-9). Site investigations conducted at the initial crossing location indicated there were very steep slopes on the east side of the river that would need significant grading. In addition, the initial pipeline route east of the crossing would need significant sidehill cuts along the slopes of the lower Missinka River valley. The amount of earthwork to construct the pipelines through this area has been substantially reduced by moving this segment of the pipeline route north.

2.4.12 Stuart River Crossing (KP 810 to KP 833)

The initial pipeline route was revised to relocate the Stuart River crossing (see Appendix D, Figure D-10). Geotechnical investigations indicated the initial crossing location was unsuitable for a crossing because of the deep-seated landslides on the east and west walls of the Stuart River valley, and because underlying layers of sands and gravels made the probability of a successful HDD very low.

To avoid routing the pipelines through Stuart River Provincial Park, which is located immediately south of the initial pipeline route, subsequent investigations focused on identifying a crossing location north of the initial crossing location. Preliminary field investigations conducted at the current crossing location indicate that both valley walls appear to be stable. Further geotechnical investigations to confirm subsurface conditions and the proposed trenchless crossing method will be conducted during detailed engineering.

Subsequent to relocating the Stuart River crossing, the pipeline route was further revised at two locations to address landowner input.

2.4.13 Boer Mountain Recreation Area (KP 915 to KP 927)

The initial pipeline route and Burns Lake Pump Station location were revised to address community input (see Appendix D, Figure D-11) regarding the Boer Mountain Recreation Area. The community suggested a revision to the initial pipeline route to avoid potential effects that might be caused on the existing and planned trail systems in this recreational area. The current pipeline route is located further north and addresses these community concerns.

2.4.14 Foxy Creek Crossing (KP 955 to KP 972)

The initial pipeline route was revised to relocate the Foxy Creek crossing (see Appendix D, Figure D-12). Field investigations conducted at the initial crossing location indicated the creek had downcut a deep, steep-walled canyon into the rock, so construction would have involved a significant amount of rock excavation. Additionally, west of the initial crossing location, the initial pipeline route traversed rock formations that may have a high acid generation potential.

The current crossing location is in an area upstream from the canyon so that rock excavation can be avoided. Additionally, the pipeline route reduces the amount of rock excavation west of the crossing.

2.4.15 Morice River Valley (KP 992 to KP 1042)

The initial pipeline route was revised to relocate the Morice River crossing and avoid crossing the Thautil River (see Appendix D, Figure D-12). The initial pipeline route generally paralleled the Morice River on the north side and geotechnical investigations indicated the initial crossing location at Morice River was unsuitable because of the presence of landslides on both sides of the river. Geotechnical investigations also indicated the initial crossing location at Thautil River, near its confluence with the Morice River, was unsuitable because of very unstable river channels in this area.

The pipeline route generally parallels the Morice River on the south side. Preliminary field investigations conducted at the current Morice River crossing location indicate that both valley walls appear to be stable. The pipeline route also avoids crossing the Thautil River.

2.4.16 Coast Mountain Area (KP 1067 to KP 1087)

The initial pipeline route was revised to improve constructability and operability of the pipelines near the Coast Mountains (see Appendix D, Figure D-13). The Coast Mountains present the most extreme topography and associated challenges for the Project. The initial pipeline route travelled overland across some very steep and rugged terrain at high elevations with very limited access for construction and operations.

Various alternative segments through the Coast Mountains were evaluated to reduce potential constructability and operability issues. These alternatives extended as far east as KP 1057 and as far west as KP 1153 (see Appendix D, Figure D-13). The pipeline route, including the Hoult and Clore tunnels, was selected for the following primary reasons:

- Construction of the Hoult and Clore tunnels along the pipeline route eliminates the need to locate the pipelines at high elevations, significantly reducing the potential constructability and operability issues associated with the initial pipeline route. Locating the pipelines at lower elevations also results in significantly reduced hydraulic pumping needs.
- The pipeline route is shorter than Alternative A.
- The pipeline route avoids the Atna River Provincial Park and a very long tunnel for Alternative A. It also avoids very steep, narrow valleys, a crossing of the Kitimat River and areas in the lower Kitimat River valley containing deposits of sensitive marine clays susceptible to slope instability, all common to Alternatives B and C.
- The pipeline route is significantly shorter than Alternative D, a more northerly route through the Williams Creek valley. It also avoids additional geotechnical and environmental disturbance issues in the Clore River and Williams Creek valleys.

The tunnel alignments and the locations of the tunnel portals were selected based on an evaluation of anticipated tunnelling conditions and the need to limit exposure to geotechnical issues at the portals (see Appendix E, Report E-2). Selection of the route for the approach segments of the pipelines to the tunnel portals considered constructability, exposure to geotechnical issues and environmental sensitivities.

2.4.17 Chist Creek to Iron Mountain (KP 1120 to KP 1142)

The initial pipeline route segment from Chist Creek to Iron Mountain was revised to avoid sensitive marine clays in the area (see Appendix D, Figure D-13). The segment of the initial pipeline route between the Chist Creek crossing and Iron Mountain (near KP 1140) crossed an area in the Kitimat River valley that is underlain by sensitive marine clays. The pipeline route is located further to the north and west onto the Onion Lake Delta and generally avoids areas where marine clays appear to be present.

2.4.18 Lower Kitimat Valley (KP 1145 to KP 1161)

The initial pipeline route segment in the Lower Kitimat River valley was revised to improve constructability and accommodate existing and proposed industrial land use (see Appendix D, Figure D-13). The pipeline route follows an existing forestry road along the west side of the Kitimat River valley, providing easier terrain for pipeline construction, better construction access and fewer watercourse crossings. As a result of consultation, the route also accommodates existing and proposed industrial land use on various properties.

2.4.19 Additional Refinements

In addition to the significant pipeline route revisions described in Sections 2.4.2 to 2.4.18, numerous smaller refinements were also made to the initial pipeline route as engineering and environmental studies and consultation progressed (see Table 2-1).

Table 2-1 Additional Refinements to the Initial Pipeline Route

Location (KP)	**Route Refinement**
0-100	• Reroutes resulting from industrial landowner negotiations • Minor reroutes to parallel existing pipelines more closely • Minor reroute to avoid potential landowner concerns • Various minor reroutes to improve constructability
100-200	• Reroute to improve Highway 43 and watercourse crossing locations • Reroute to improve Pembina River crossing location • Various minor reroutes to improve constructability
200-300	• Minor reroutes to parallel existing pipelines more closely • Minor reroutes to avoid well sites and other existing facilities • Various minor reroutes to improve constructability • Various minor reroutes at watercourse crossings resulting from SWAT field program
300-400	• Minor reroutes to avoid unstable slopes at some river crossings
400-500	• Minor reroutes to avoid unstable slopes at some river crossings • Minor reroutes to avoid existing facilities • Various minor reroutes at watercourse crossings resulting from SWAT field program
500-600	• Reroute to improve Five Cabin Creek crossing location • Reroute to improve Kinuseo Creek crossing location • Reroute to improve Murray River crossing location • Reroute to move the Tumbler Ridge pump station out of the Greg Duke Memorial Forest Reserve • Various minor reroutes to improve constructability • Various minor reroutes at watercourse crossings resulting from SWAT field program

Table 2-1 Additional Refinements to the Initial Pipeline Route (cont'd)

Location (KP)	Route Refinement
600-700	• Various reroutes to improve constructability through the Continental Divide • Reroute to improve Missinka River crossing • Reroute to avoid wetland area • Minor reroute to avoid existing facilities • Various minor reroutes to improve constructability • Various minor reroutes at watercourse crossings resulting from SWAT field program
700-800	• Reroute to avoid Sas Mighe Indian Reserve 32 • Reroute to improve railway and road crossings • Various minor reroutes to improve constructability • Various minor reroutes at watercourse crossings resulting from SWAT field program
800-900	• Minor reroutes to avoid unstable slopes on some river crossings • Various minor reroutes at watercourse crossings resulting from SWAT field program
900-1000	• Reroute to avoid Poison Creek Indian Reserve 17 • Minor reroute to address community input and to relocate Buck Creek crossing • Minor reroute to avoid potential landowner concerns • Two minor reroutes to avoid goat ranges • Various minor reroutes to improve constructability • Various minor reroutes at watercourse crossings resulting from SWAT field program
1000-1172	• Minor reroutes to avoid areas underlain by sensitive marine clays • Reroute to avoid industrial land use concerns • Reroutes to accommodate other potential pipeline projects • Reroute to accommodate Kitimat Terminal site layout and tie-in location • Various minor reroutes to improve constructability • Various minor reroutes at watercourse crossings resulting from SWAT field program
NOTE: SWAT – Sensitive Watercourse Assessment Team	

All of the revisions and refinements described in Sections 2.3 and 2.4 have been incorporated into the applied-for pipeline route.

2.5 Intermediate Pump Station Locations

Upon determining the pipeline route, the general locations for the intermediate pump stations were selected to optimize system hydraulics, with consideration for environmental, stakeholder and lifecycle cost interests. The intermediate pump station locations were further refined based on the following considerations:

- ability to co-locate oil and condensate pump stations

- proximity to existing road access and electric power
- site conditions, including topography, surface drainage and soils
- environmental constraints, including sensitive habitat, proximity to water bodies and wetlands and archaeological sites
- land ownership and land use considerations, including proximity to residences

For the proposed locations for the intermediate pump stations, see Appendix C, Figures C-1 to C-14 and Tables 4-3 and 4-6 in Section 4.

2.6 Potential Pipeline Route and Pump Station Location Refinements under Consideration

Based on recently received information, the following potential refinements are currently under evaluation:

- proposed Fort Hills Upgrader site lands (KP 7 to KP 14) based on industrial development needs
- Altalink/Epcor Heartland Transmission Project 'West' alternate route would parallel the proposed Northern Gateway alignment between KP 16 and KP 48. Amendments to the route may be required to match a potentially approved powerline corridor. Discussions with the proponents are ongoing.
- Little Smoky Caribou Range (KP 319 to KP 337) based on an Alberta Sustainable Resources Development request to consider route alternatives in this area
- Western Alberta (KP 426 to KP 522) based on an Alberta Sustainable Resources Development request to consider the potential use of an approved pipeline route for a SemCAMS project
- Necoslie River area (KP 814 to KP 816) based on landowner input
- Whitecourt Pump Station location based on an Alexis Nakota Sioux Nation request
- Bear Lake Pump Station location based on a MacLeod Lake First Nation request

Any changes to the pipeline route and pump station locations will be filed with the NEB.

2.7 Detailed Pipeline Route

The detailed pipeline route will be finalized within the 1-km wide project pipeline corridor during detailed engineering. The detailed route will incorporate detailed engineering, construction, and operations considerations, further site-specific constraint mapping, results of Aboriginal Traditional Knowledge studies and further field investigations, and input from participating Aboriginal groups and communities, landowners, the public, other interested parties and government agencies.

3 Geotechnical Conditions

3.1 Pipeline Route

The pipeline route crosses six physiographic regions between the Bruderheim Station and Kitimat Terminal. For the approximate locations of the physiographic regions along the pipeline route, see Table 3-1.

Table 3-1 Physiographic Regions – Locations along the Pipeline Route

Physiographic Region	Approximate Kilometre Post		Approximate Location	
	From	To	From	To
Eastern Alberta Plains	0	166	Bruderheim	Greencourt
Southern Alberta Uplands	166	516	Greencourt	Alberta–British Columbia boundary
Alberta Plateau	516	560	Alberta–British Columbia boundary	Kinuseo Creek
Rocky Mountains	560	663	Kinuseo Creek	Parsnip River
Interior Plateau	663	1067	Parsnip River	Gosnell Creek
Coast Mountains	1067	1172	Gosnell Creek	Kitimat Terminal

The following sections describe the physiographic regions and identify the primary geotechnical considerations associated with the pipeline route in each region. The geotechnical considerations to be addressed and standard mitigation measures are summarized in Table 3-2. These considerations will be addressed during detailed engineering so that the pipelines are properly designed to meet pipeline integrity, operational safety and environmental considerations. For the geotechnical report for the pipeline route, see Appendix E, Report E-1.

Table 3-2 Primary Geotechnical Considerations and Standard Mitigation Measures

Primary Geotechnical Considerations	Standard Mitigation Measures
Deep seated slides	• locate pipelines and facilities to avoid deep seated slides • install ground and surface water control • install berm and riprap toe reinforcements • site monitoring
Shallow to moderately deep slides	• locate pipelines and facilities to avoid slides • install ground and surface water control • design cuts and fills to minimize instability • install anchors, shotcrete or mechanical stabilized earth

Table 3-2 Primary Geotechnical Considerations and Standard Mitigation Measures (cont'd)

Primary Geotechnical Considerations	Standard Mitigation Measures
Rock falls and rock toppling	• locate pipelines and facilities to avoid rock falls • design rock cuts to minimize instability • install stabilization measures, including scaling, anchoring, shotcrete, and mesh • install rock fall protection measures, including berms, catchment areas and ditches • install reinforced concrete slabs over pipelines in selected areas • remove potential problem boulders on slopes
Debris flows	• locate pipelines and facilities to avoid debris flows • locate above ground structures away from alluvial fans and streams subject to debris flow • install pipelines at a deeper depth in selected areas • install concrete coated pipe in selected areas • install debris flow berms • monitor weather and snow melt conditions during construction in areas subject to debris flows, and remove personnel and equipment if necessary • set temporary bridges to appropriate elevations on debris flow streams during construction
Avalanches	• locate pipelines and facilities to avoid avalanches • consider avalanche issues when locating key facilities such as tunnel portals that will require year round construction • conduct avalanche monitoring and control during construction • conduct avalanche monitoring and control where required during operations • install pipeline at a deeper depth or install a concrete coated pipe in locations prone to avalanche caused avulsion
Sedimentation and erosion	• design cuts and fills to minimize sedimentation and erosion • install ground and surface water control • avoid diversion of surface water flows along the pipeline • install silt fencing and temporary water control, revegetate disturbed areas • install sedimentation ponds, sediment collection berms and filtration berms in selected areas
Karst	• locate pipelines and facilities to avoid karst formations

Table 3-2 Primary Geotechnical Considerations and Standard Mitigation Measures (cont'd)

Primary Geotechnical Considerations	Standard Mitigation Measures
Acid rock drainage (ARD)	• locate pipelines and facilities to avoid ARD • conduct visual assessment followed by sampling and analysis, when required, during construction • implement mitigation measures, including disposal, in designated areas where oxidation will be avoided (capped or under water), mixing with buffer material and shotcreting of bedrock surfaces • ARD mitigation protocols will conform with Guidelines for Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia
Seismicity	• locate pipelines and facilities away from areas of potential liquefaction • design pipelines and facilities to current seismic standards
Marine clays	• locate the pipelines and facilities away from areas of potentially sensitive marine clays • conduct detailed stability analysis during detailed engineering
Tsunamis	• locate facilities away from areas of high tsunami risk • design facilities to limit potential tsunami impacts

3.1.1 Eastern Alberta Plains

The pipeline route crosses the Eastern Alberta Plains physiographic region from Bruderheim to Greencourt for approximately 166 km. The topography is flat to gently rolling with stream valleys incised tens of metres below the surrounding plains.

Watercourse crossings along this section of the pipeline route include the North Saskatchewan, Pembina and Paddle Rivers.

The overburden material along this section of the route includes medium to high plastic silty clay, glacial tills and glaciolacustrine (glacial lake) deposits that consist of silts and medium to high plastic clays with some sand layers. The bedrock that underlies the region is flat lying and consists of weak sandstones, siltstones and clay shales, all of which contain occasional weak bentonite seams.

Subsurface conditions within this region are generally favourable for pipeline construction. The primary geotechnical consideration is localized presence of landslides on valley slopes. The pipeline route avoids such areas wherever possible. In locations where it was not possible to avoid existing landslides, mitigation measures will be incorporated in the detailed engineering and implemented during construction to limit the potential effects of ground movements on the pipelines.

3.1.2 Southern Alberta Uplands

The pipeline route crosses the Southern Alberta Uplands physiographic region from Greencourt to the Alberta–British Columbia boundary for approximately 350 km. The topography in this area is gently rolling and river valleys are generally deeper than those within the Eastern Alberta Plains.

Watercourse crossings along this section of the pipeline route include the Athabasca, Simonette, the Smoky and the Wapiti Rivers.

The overburden materials along this section of the route are similar to those encountered within the Eastern Alberta Plains and include silty clay tills and glaciolacustrine deposits consisting of loose silts and medium to high plastic clays.

The underlying bedrock is flat lying and consists of weak sandstones, siltstones and clay shales, all of which contain occasional bentonite seams. Landslides, seated in either the glaciolacustrine/glacial till deposits or the underlying bedrock, are common on many of the river and stream valleys.

Subsurface conditions within this region are generally favourable for pipeline construction. The primary geotechnical consideration is the widespread presence of existing landslides on valley slopes. The pipeline route was selected to avoid such areas wherever possible. In locations where it was not possible to avoid existing landslides, mitigation measures will be incorporated in the detailed engineering and implemented during construction to limit the potential effects of ground movements on the pipelines.

3.1.3 Alberta Plateau

The pipeline route crosses the Alberta Plateau from the Alberta–British Columbia boundary to Kinuseo Creek for approximately 44 km. The topography ranges from rolling to steep in some locations.

Watercourse crossings along this section of the pipeline route include the South Redwillow River.

Overburden materials are more variable than those of the Southern Alberta Uplands and include silty clay glacial tills, glaciolacustrine silts and clays, colluvial (gravity-transported material), glaciofluvial (glacial river) and occasional thick organic deposits.

The underlying bedrock consists of limestone, sandstones, siltstones and shales that range in strength from moderately strong to very strong. The bedrock is generally stronger and contains less clay than the bedrock that underlies the Southern Alberta Uplands and. Therefore, natural slopes are generally more stable in the Alberta Plateau physiographic region than those in the Southern Alberta Uplands physiographic region.

Subsurface conditions within this region are generally favourable for pipeline construction.

3.1.4 Rocky Mountains

The pipeline route crosses the Rocky Mountains physiographic region from Kinuseo Creek to the Parsnip River for approximately 103 km. Widespread folding and faulting of the bedrock in this region has produced aligned ridges that are dissected into alpine and valley terrain. The topography is controlled by the underlying bedrock and is rugged with steep slopes in many locations.

The pipeline route follows river valleys, where practical. A wide variety of overburden materials are present along the route, although glacial till, glaciolacustrine silts and clays, glaciofluvial (glacial river) deposits, colluvium (gravity-transported material) and exposed bedrock are most common.

Watercourse crossings along this section of the pipeline route include Kinuseo Creek and the Murray and Missinka Rivers.

Rock types include limestone, dolomite, quartzite and other metamorphic rocks in addition to conglomerate, sandstones, siltstones and shale. These rocks range from moderately strong to very strong, and their mechanical behaviour is typically controlled by the frequency and orientation of discontinuities such as joints, fractures and faults. Karst (underground voids or caves) exist in some areas, and all known locations were avoided when selecting the pipeline route. There is potential for acid rock drainage in a few areas.

Construction along this section of the pipeline route is expected to be challenging because of the rugged terrain and the presence of hard rock at or near ground surface.

The following geotechnical considerations will be addressed during detailed engineering:

- rock falls and rock toppling failures on natural slopes and excavated rock cuts
- shallow slides and poor travel conditions for vehicles and equipment, particularly in wet soils, glaciolacustrine soils and organic materials
- control of sedimentation and erosion
- stability of cuts for grade construction
- debris flows in locations where the pipelines cross steep mountain streams
- avalanche runouts
- detection, disposal and mitigation of potential acid generating rock from excavations

3.1.5 Interior Plateau

The pipeline route crosses the Interior Plateau physiographic region from the Parsnip River to Gosnell Creek for approximately 404 km. The terrain is rolling to ridged. Some of the stream valleys are deeply incised, but many are wide with gentle to moderate slopes. Drumlins and similar topographic forms (elongate ridges) dominate much of the area.

Watercourse crossings along this section of the pipeline route include the Parsnip, Crooked, Salmon, Stuart, Endako and Morice Rivers and Gosnell Creek.

Much of the overburden material in the Interior Plateau physiographic region consists of glacial till deposits. However, extensive glaciofluvial (sand and gravel) and glaciolacustrine (silty and clay) deposits and occasional eskers (sand and gravel) occur. Colluvium (gravity-transported material) occurs on some slopes and as talus below rock bluffs. Eskers (sand and gravel ridges) and organic deposits are also present. Deep organic deposits occur in the bottoms of a few valleys.

The bedrock that underlies the Interior Plateau is primarily volcanic rock, including basalt, andesite and gabbros and metamorphosed equivalents. Metamorphosed sedimentary rocks are also common, including sandstones (greywacke), siltstones and shales. These rocks are typically moderately strong to very strong, and their mechanical behaviour is controlled by the frequency and orientation of discontinuities. Rocks prone to acid rock drainage may be present in a few areas.

Subsurface conditions within the Interior Plateau are generally favourable for pipeline construction, although the presence of hard rock near ground surface and steep slopes in some locations will present challenges. Geotechnical considerations within the Interior Plateau region will also be addressed during detailed engineering, including slope instabilities, potential for acid generating rock, grading and slope stability where steep slopes occur, sedimentation and erosion, and movement of equipment and vehicles, and trench stability in a few areas of deep organic deposits.

3.1.6 Coast Mountains

The pipeline route crosses the Coast Mountains physiographic region from Gosnell Creek to Kitimat for approximately 105 km. The topography in this region is rugged with sections of steep, high slopes, incised canyons and areas of exposed bedrock.

Watercourse crossings along this section of the pipeline route include the Clore, Wedeene and Little Wedeene Rivers.

On the east side of the Coast Range, the pipeline route is located within the Gosnell Creek and Clore River valleys. Glacial till of variable thickness mantles the slopes of these valleys. During deglaciation, the valleys were partially infilled with glaciofluvial and glaciolacustrine deposits that now overlie the till. Sensitive marine clay occurs in the Lower Kitimat Valley.

At higher elevations within the Coast Range, exposed rock is common and the topography is rugged.

On the west side of the Coast Mountains, the pipeline route follows portions of the Kitimat River and its tributaries. At higher elevations in these valleys, the near surface material consists of glacial till, colluvium and exposed bedrock. Debris flows, rock instabilities and soil slope failures associated with high groundwater conditions, occur in localized areas. Rock avalanches are also known to occur, but the pipeline route was selected to avoid all areas identified, although they may remain a concern on some access roads.

Extensive deposits of clay deposited in a marine (salt water) environment are present at lower elevations in the Kitimat Valley. Some of this material is sensitive and the strength of this material can drop significantly, possibly resulting in slides. The pipeline route was selected to avoid these deposits in most locations. In the few locations where it was not possible to avoid such areas, site-specific mitigation measures will be incorporated in the design and implemented during construction.

On the east side of the Coast Range, bedrock along the pipeline route consists of metamorphosed sandstones, siltstones and shales and volcanic rocks, ranging from moderately strong to strong. Farther west, the bedrock consists of volcanic rocks, limited sedimentary rocks and intrusive granitic and similar rocks, most of which range from strong to very strong. The mechanical behaviour of most of these rocks is controlled by the presence of discontinuities within the rock mass, including joints, fractures and faults.

Subsurface conditions within the Coast Mountain physiographic region present construction challenges because of the rugged terrain and the presence of hard rock at or near ground surface. In addition, the following identified geotechnical issues will be addressed during detailed engineering:

- rock falls, rock toppling failures on natural slopes and cut excavations
- debris flows along steep valleys

- soil slope failures
- control of sedimentation and erosion
- avalanche runouts
- detection, disposal and mitigation of potential acid generating rock from excavations
- effects of potential seismic activity
- effects of instability of the sensitive marine clays

3.2 Hoult and Clore Tunnels

Two tunnels will route the oil and condensate pipelines through the Coast Mountains. The tunnels will be located between the Clore River valley and the Hoult Creek valley between KP 1072.9 and KP 1086.8 (see Appendix C, Figure C-13). The east or Clore tunnel will be approximately 6.5 km long and will cross through North Hope Peak. The west or Hoult tunnel will be approximately 6.6 km long and will cross through Nimbus Mountain.

The geology of the North Hope Peak and Nimbus Mountain area consists primarily of volcanic and plutonic rocks with steeply dipping northeast to northwest trending faults. Initial assessments of anticipated tunnelling conditions for the Hoult and Clore tunnels were developed based on a preliminary geotechnical investigation program conducted in 2006. The program included geological mapping and diamond drilling at key locations. Initial estimates of tunnelling conditions were prepared based on interpreted geological sections and estimated rock mass properties.

Fault zones were identified as areas with poor rock mass quality and potential areas for groundwater inflows. Preliminary evaluations for potential acid generating rock were completed as part of the initial investigation work. These results indicated there was low probability of encountering acid generating rock during construction of the tunnels.

For the geotechnical report, see Appendix E, Report E-2. Geotechnical considerations will be addressed during detailed engineering so that the tunnels are properly designed to meet pipeline integrity, operational safety and environmental considerations.

3.3 Kitimat Terminal

The Kitimat Terminal site is underlain by bedrock consisting of moderately strong to strong metamorphic and igneous rocks. The stability and bearing capacity of the bedrock is largely determined by discontinuities within the rock mass and can vary greatly over relatively short distances.

At the Kitimat Terminal site, the depth to bedrock ranges from surface exposure to approximately 25 m. The overburden soils consist primarily of firm to stiff, low to medium plastic clays. The in-situ strength and compressibility of the clay is highly variable and it may become unstable when disturbed, either by construction activity or seismic events. The material is not considered suitable as a foundation for structures that cannot tolerate substantial settlements.

Overburden soils and underlying bedrock will be excavated, as necessary, to achieve the needed design grades. The tank bases will be supported on concrete foundations or granular tank pads, either of which will be founded on bedrock. Other major buildings and structures will be supported on concrete foundations (piles or footings) that, in turn, will be founded directly on the underlying bedrock. Smaller buildings will likely be supported on gravel pads.

The ground surface will be graded and sloped to direct surface water into the remote impoundment reservoir planned for the southwest side of the tank terminal.

For the geotechnical report, see Appendix E, Report E-3. Geotechnical considerations will be addressed during detailed engineering so that the Kitimat Terminal is properly designed to meet integrity, operational safety and environmental considerations. The primary considerations include the following:

- foundation and supports for the tanks, tanker and utility berths, and other infrastructure
- rock falls and rock toppling failures on existing rock slopes and in excavated cut slopes
- detection, disposal and mitigation of potential acid generating rock from excavations
- differential settlements under the oil and condensate tanks
- potential instability of the marine clays
- diversion, collection and disposal of stormwater and surface runoff water during and after construction
- potential effects of tsunami activity
- potential effects of seismic activity

4 Hydraulic Design

4.1 General

Steady-state hydraulic analyses were undertaken to determine the optimum pipe diameter, pump station locations and design pressure to achieve the average annual capacities of the oil and condensate pipelines. The analyses considered a range of pipeline diameters, pump station locations and design pressures. A transient analysis will be performed on the pipelines during detailed engineering to evaluate particular operational conditions.

4.2 Oil Pipeline

4.2.1 Design Capacity

The oil pipeline system will deliver an average annual volume of 83,400 m^3/d (525,000 bbl/d).

Typically, over a one-year period, a pipeline system can be expected to achieve an overall average daily capacity equal to 90% of the theoretical design capacity. See Table 4-1 for a summary of the capacities of the Project's oil pipeline.

Table 4-1 Oil Pipeline Capacities

Parameter	Percentage of Theoretical Design Capacity	Capacity	
		m^3/d	bbl/d
Average annual capacity	90	83,400	525,000
Theoretical design capacity	100	92,700	583,000

4.2.2 Oil Properties

The oil pipeline will transport a variety of low vapour pressure (LVP) hydrocarbons, such as synthetic oil and diluted bitumen. Because Northern Gateway's oil pipeline will operate as a batched pipeline, the hydraulic analysis assumed that the hydrocarbon with the highest viscosity, diluted bitumen, will govern the flow rate in the oil pipeline. See Table 4-2 for the diluted bitumen properties used for the hydraulic analysis.

Table 4-2 Properties of Diluted Bitumen

Properties	Diluted Bitumen	
Temperature (°C)	11.9	21.2
Viscosity @ temp. (cSt)	350	177
Density @ temp. (kg/m^3)	937	933
TVP (kPa @ temp.)	20.9	36.1
Density @ 15°C (kg/m^3)	935	
Reid vapour pressure (kPa)	64.3	
Average sulphur (%w/w)	2.7	
Ni plus V ppm	276	

4.2.3 Hydraulic Design Results

Hydraulic engineering parametric analyses were undertaken to optimize the pipeline and pump station system configuration based on a hydraulics comparison. The analyses considered a range of pipeline diameters, pump station locations and design pressures.

Based on an average annual capacity of 83,400 m^3/d (525,000 bbl/d), a 914-mm OD pipeline with seven pump stations was selected as the optimum configuration for the oil pipeline.

The hydraulic design also incorporates the potential to expand the system capacity by adding additional pump stations and pumping facilities. Any proposed expansion would be the subject of future regulatory applications.

See Table 4-3 for the locations of the pump stations along the oil pipeline and the typical discharge pressure at each location.

Table 4-3 Oil System Pump Station Discharge Pressure

Pump Station	Approximate Kilometre Post	Typical Discharge Pressure at Design Rate (kPa)
Bruderheim	0	14,507
Whitecourt	203.2	14,127
Smoky River	400.6	14,679
Tumbler Ridge	598.1	9,880
Bear Lake	716.0	9,170
Fort St. James	824.5	10,611
Burns Lake	925.5	10,859

4.3 Condensate Pipeline

4.3.1 Design Capacity

The condensate pipeline will deliver an average annual volume of 30,700 m^3/d (193,000 bbl/d). The annual and theoretical design capacities for the condensate pipeline were calculated on the same basis as described for the oil pipeline. For the results, see Table 4-4.

Table 4-4 Condensate Pipeline Capacities

Parameter	% of Theoretical Design Capacity	Capacity per day	
		m^3	bbl
Average annual capacity	90	30,700	193,000
Theoretical design capacity	100	34,100	214,000

4.3.2 Condensate Properties

The condensate pipeline will operate as a LVP pipeline to transport condensate from various overseas sources. However, significant variations in condensate properties are not expected. For a summary of the condensate properties used for the hydraulic analysis, see Table 4-5.

Table 4-5 Condensate Properties

Properties	Condensate	
Temperature (°C)	10	20
Viscosity @ temp. (cSt)	0.77	0.66
Density @ temp. (kg/m^3)	719	711
TVP (kPa @ temp.)	34.2	56.9
Density @ 15°C (kg/m^3)	715	
Reid vapour pressure (kPa)	79	
Ave. Sulphur (%w/w)	0.13	

4.3.3 Hydraulic Design Results

Hydraulic engineering parametric analyses were undertaken to optimize the pipeline and pump station system configuration. The analyses considered a range of pipeline outside diameters, pump station locations and design pressures.

Based on an average annual capacity of 30,700 m^3/d (193,000 bbl/d), a 508-mm OD pipeline with nine pump stations was selected as the optimum configuration recognizing that, where practical, it would be beneficial to situate the condensate pump stations at the same locations as those established for the oil pipeline. This resulted in six of the condensate pump stations being co-located with the oil pump stations.

The hydraulic design also incorporates the potential to expand the system capacity by adding additional pump stations and pumping facilities. Any proposed expansion would be the subject of future regulatory applications.

See Table 4-6 for the locations of the pump stations along the condensate pipeline and the typical discharge pressure at each location.

Table 4-6 Condensate System Pump Station Discharge Pressure

Pump Station	Approximate Kilometre Post	Typical Discharge Pressure at Design Rate (kPa)
Kitimat	1172.2	2,779
Clearwater	1124.7	10,404
Houston	1002.0	7,081
Burns Lake	925.5	7,267
Fort St. James	824.5	7,046
Bear Lake	716.0	11,032
Tumbler Ridge	598.1	8,377
Smoky River	400.6	8,729
Whitecourt	203.2	8,446

5 Pipeline Design

5.1 Line Pipe

Line pipe for the oil and condensate pipelines will be made of low carbon, high strength, low alloy Grade 483 (X70) steel and will be produced by either the longitudinal or helical seam welding process. The line pipe for the oil and condensate pipelines will be manufactured to CSA Z245.1, Steel Pipe or to American Petroleum Institute standard American Petroleum Institute (API) Spec 5L, Specification for Line Pipe.

For the design parameters to be used for the oil pipeline, see Table 5-1.

Table 5-1 Oil Pipeline Design Parameters

Item	Line Pipe
Outside diameter (mm)	914
Max. design pressure range (kPa)	8,707-16,755
CSA notch toughness category	I
Design factor	0.8
Min. design temperature (°C)	-5
Max. design temperature (°C)	50
Material grade (MPa)	483
Min. Wall thickness range (mm)	10.3-19.8
Estimated length (km)	1,172

For the design parameters to be used for the condensate pipeline, see Table 5-2.

Table 5-2 Condensate Pipeline Design Parameters

Item	Line Pipe
Outside diameter (mm)	508
Max. design pressure range (kPa)	9,650-12,040
CSA notch toughness category	I
Design factor	0.8
Min. design temperature (°C)	-5
Max. design temperature (°C)	50
Material grade (MPa)	483
Min. Wall thickness range (mm)	6.4-7.9
Estimated length (km)	1,172

In addition to the quantities of line pipe shown in Table 5-1 and Table 5-2, short lengths of heavy-wall pipe will be needed for crossing railways, roads and major rivers. The lengths and wall thicknesses of these additional heavy-wall sections will be determined based on engineering assessments performed during detailed engineering.

The pipelines will operate as LVP pipelines.

CSA Category 2 line pipe will be specified for those locations, if any, where air testing of the pipelines is determined to be the preferred method.

The feasibility of using Grade 550 (X80) steel and associated reduced wall thicknesses for all, or a portion of, the oil pipeline will be evaluated during detailed engineering.

5.2 Welding

The field girth welding of line pipe for the oil and condensate pipelines will be by mechanized gas metal arc welding (GMAW) or manual shielded metal arc welding (SMAW).

The tie-in welding for both pipelines will likely involve a combination of manual SMAW and semi-automatic arc welding. All field girth welds will be non-destructively inspected using ultrasonic or radiographic inspection methods.

A joining program will be developed consistent with OPR-99 and all NDE Inspectors and welders will be qualified in accordance with CSA Z662-07.

5.3 Protective Coatings

Protective coatings will be used as the primary external corrosion control measure for the oil and condensate pipelines. Line pipe for the pipelines will be coated with fusion bond epoxy applied at a coating plant. The use of a three-layer system comprised of fusion bond epoxy, adhesive and polyethylene layers for either a portion or the entire length of the pipelines will be evaluated during detailed engineering.

Line pipe for HDD or bored sections of the pipelines will receive an additional abrasive resistant coating to protect the base coating. During construction, rock shield, sand padding, wooden lagging or concrete coating will also be used, where needed, to provide additional mechanical protection for the pipe coating.

Field girth welds will be coated with a system compatible with the plant-applied external coating system. Buried block valve assemblies and other underground appurtenances will be coated with a suitable corrosion control system such as an epoxy/urethane system.

The pipelines will not transport hydrocarbons containing significant corrosive substances and therefore an internal pipe coating will not be needed.

5.4 Cathodic Protection

Cathodic protection (CP) will be used as a secondary corrosion control measure for the oil and condensate pipelines. The CP system for the pipelines will be designed and installed in accordance with the applicable codes and regulations and Enbridge's engineering standards and specifications. Ongoing CP monitoring will be in accordance with CSA Z662-07 and Canadian Gas Association (CGA) Standard OCC-1-2005. Where portions of the pipelines will be in proximity to, or will parallel, alternating current powerlines, CSA Z662-07 and Can/CSA-C22.3 No. 6 will be followed. The CP system will be designed to connect to the local power grid.

The oil and condensate pipelines will share a common RoW and will be made electrically continuous through continuity bonding. This electrical continuity will provide common CP to both pipelines. The continuity bonding will be provided by means of multiple negative cables at the CP locations, plus at other intermediate bond locations as needed.

Test stations for long-term monitoring of CP levels in accordance with CSA Z662-07 will be installed at appropriate intervals along the pipelines to confirm the effectiveness of the applied CP current and permit pipeline access for other corrosion control monitoring activities. Test stations will also be installed at cased road and railway crossings, if present, and at other existing pipeline crossings, as necessary.

The pipelines will be electrically isolated from the pump stations so that the available pipeline CP current remains with the pipelines. Monolithic (weld-in type) isolators will be installed where the pipelines enter and exit the pump stations. Standard flange insulation kits will be employed to isolate drain lines or other piping that may bypass the pipeline insulation.

5.5 Valves, Flanges and Fittings

Valves will be installed at strategic locations along the oil and condensate pipelines, including at pump stations, major river crossings and other locations based on a review of engineering, environmental, Aboriginal traditional knowledge studies, geotechnical and volume factors and operation and maintenance needs.

A preliminary list of valve locations was determined using Enbridge's valve location assessment process (see Appendix F, Table F-1). This process incorporates considerations for potential release volumes, environmental sensitivity and potential environmental effects. Potential release volumes were calculated with a comprehensive proprietary model using a detailed profile of the proposed pipelines. Risk was assessed by a team of discipline experts. Specific locations were also adjusted taking into account terrain and service access requirements.

The number of pipeline valves and their locations will be finalized during detailed engineering.

For typical pipeline valve site plans, see Appendix F, Figures F-1 and F-2. Each remotely operated valve will be equipped with communication capability. The need for pressure monitoring at the valves will be determined during detailed design.

All pipeline valves on the oil and condensate pipelines will be full-port valves with electric motor operators. Electrical power for the block valves will be obtained from local utility companies where practical, or from alternative power sources which include thermo-electric generators and solar panels.

A combination of wide-area network , telephone lines, satellite and radio communication will provide main and backup (where required) communication systems for remote operation of the valves. The infrastructure, including radio communication towers and pressure indicating transmitters, associated with the selected communication systems will be determined during detailed engineering.

Valves and fittings will be designed, manufactured and tested in accordance with CSA Z662-07 and the following standards:

- CSA Z245.11-05, Steel Fittings
- CSA Z245.12-05, Steel Flanges
- CSA Z245.15-05, Steel Valves

All valves and fittings will be compatible with the line pipe to which they are connected.

5.6 Scraper Trap Facilities

Scraper trap facilities will be installed on the oil and condensate pipelines at the Bruderheim Station and Kitimat Terminal and at selected intermediate pump stations. These assemblies will be capable of launching or receiving the latest models of in-line inspection tools, as well as standard cleaning scrapers used for batching, cleaning and verifying pipeline integrity. The locations of the scraper trap facilities will be finalized during detailed engineering.

Intermediate oil pump stations will normally operate with bypass assemblies in place. When necessary for in-line inspection or other purposes, the bypass assemblies will be removed and the scraper trap assemblies will be connected.

The scraper trap end closures will be a “quick-opening closure” with pressure interlock protective systems, to safeguard against the door being opened when the trap is pressurized, as specified under CSA Z662-07. The pipe and barrel sections of the scraper trap assemblies will be made of low carbon, high strength, low alloy steel or quenched and tempered carbon steel and will be produced from either formed pipe or rolled plate. The selection of materials will be determined during detailed engineering. The pipe will be manufactured to CSA Z245.1 standards.

For the design parameters for the scraper trap facilities, see Tables 5-3 and 5-4. The barrel outside diameters, material grade and wall thicknesses for the various components of the oil and condensate scraper trap facilities may change depending on the particular manufacturer.

Table 5-3 Scraper Trap Facility Design Parameters – Oil Pipeline

Design Parameter	Line Pipe	Barrel Pipe
Outside diameter (mm)	914	1067
CSA notch toughness category	II	II
Max. design pressure (kPa)	14,900	14,900
Design factor	0.6	0.6
Scraper trap pressure rating	PN 150	PN 150
Min. design temperature (°C)	-45	-45
Max. design temperature (°C)	50	50
Grade of steel (MPa)	483	483
Min. wall thickness (mm)	23.50	27.45

Table 5-4 Scraper Trap Facility Design Parameters – Condensate Pipeline

Design Parameter	Line Pipe	Barrel Pipe
Outside diameter (mm)	508	610
CSA notch toughness category	II	II
Max. design pressure (kPa)	14,900	14,900
Design factor	0.6	0.6
Scraper trap pressure rating	PN 150	PN 150
Min. design temperature (°C)	-45	-45
Max. design temperature (°C)	50	50
Grade of steel (MPa)	483	483
Min. wall thickness (mm)	13.06	15.67

5.7 Class Location

The oil and condensate pipelines will operate as LVP pipelines. As specified in Table 4.2 of CSA Z662-07, a class location factor of 1.0 can be used at all locations for the design of LVP pipelines, except for uncased railway crossings where the class location factor must be reduced to 0.625.

5.8 Minimum Depth of Cover

The minimum installation depth of cover from construction grade for the pipelines will comply with applicable codes and Enbridge standards (see Table 5-5).

Table 5-5 Minimum Depth of Cover

Location	Minimum Depth of Cover (Construction Grade) (m)	Minimum Depth of Cover at Centreline of Road or Rail Bed (m)	Minimum Depth of Cover (in Rock) (m)
General	0.9	N/A	0.6
Paved roads	1.2	1.5	1.2
Improved roads	1.2	1.2	1.2
Access roads and trails	0.9	1.2	0.6
Railways	2.0	3.05	2.0
Watercourses	1.2	N/A	0.6
NOTE: N/A — not applicable			

5.9 Pipeline Crossings

The pipelines will cross below existing roads, railway lines, other existing pipelines and utility lines (see Table 5-6 for the estimated number of crossings). All crossings will be designed and constructed to conform to NEB regulations.

Table 5-6 Road, Railway and Pipeline Crossing

Crossing Feature Type	Estimated Number of Crossings
Existing pipelines	473
Railways	12
Highways	20
Grid roads	260
Access roads	441
Total	**1,206**

The loads imposed on the pipelines by road and rail traffic will be considered in the design of these crossings.

Generally, bored crossings will be used below paved highways and railway lines to avoid disruption of service. However, in locations where the pipelines cross unpaved roads that carry very low traffic volumes, consideration will be given to constructing the pipeline crossings using open-cut procedures.

Existing pipelines and utility lines will generally be crossed using open-cut procedures.

5.10 Buoyancy Control

Buoyancy control may be needed along those sections of the pipelines located under watercourses and in wetlands. Pipe weights, concrete coating or screw anchors will be used to provide buoyancy control, as necessary. Optimization of these methodologies to maintain the stability of the pipeline system will be determined during detailed engineering.

5.11 Pressure Testing

Generally, the pipelines will be designed to accommodate hydrostatic testing in accordance with OPR-99 and CSA Z662-07. However, specific sections of the pipelines may be designed to accommodate air testing if it is determined to be the preferred testing method. The selection of pipeline sections to be considered for air testing will be determined during detailed engineering. Prior to the pressure testing, a pressure testing program will be developed and provided to the NEB, as needed.

5.12 Signs and Markers

Following completion of construction, but before operations begin, signs and markers will be placed to warn the public and any third-party utility companies of the presence of the pipelines. Marker signs will be placed:

- where the pipelines enter and exit road RoWs
- on the support posts of the chainage markers installed at pre-determined intervals along the pipeline route
- near foreign pipeline crossings
- back from the top edge of both sides of watercourse crossings
- directly above the pipelines on fence lines that are crossed
- directly above the pipelines at pump station and valve sites
- on posts near cathodic protection test lead junction boxes

5.13 Permanent Access Roads

Permanent access roads will be constructed, where needed, to valve sites, tunnel portals and environmental response control points.

5.14 Unspecified Conditions

Localized conditions along the pipeline route and standard mitigation measures that are not specifically addressed in CSA Z662-07 are summarized in Table 5-7.

During detailed engineering, qualified professional engineers will assess, prepare and certify designs to safeguard the pipelines and the environment from the potential adverse effects of conditions that are not specifically addressed in CSA Z662-07.

Table 5-7 Localized Conditions and Standard Mitigation Methods

Localized Condition	Standard Mitigation Methods
Various geotechnical considerations	• refer to Section 3.1 Table 3-2 Primary Geotechnical Considerations and Standard Mitigation Methods
Watercourse scour	• design and install crossing with appropriate scour depth consideration • install concrete coated pipe where required
Pipeline buoyancy control	• install buoyancy control devices such as screw anchors, concrete or saddle weights, concrete coated pipe
Aerial crossings	• design, construct and operate aerial crossing structures in accordance with applicable codes and standards
Pipeline tunnels	• design, construct and operate pipeline tunnels in accordance with applicable codes and standards • refer to Section 7 Clore and Hoult Tunnels for additional information

6 Watercourse Crossings

6.1 General

The pipelines will cross 773 identified watercourses with defined bed and banks; 669 of the crossings are fish-bearing.

The most suitable method for a pipeline watercourse crossing considers a number of factors, such as:

- fish and fish habitat, including the species and life stages that are anticipated to be present in the potential zone of influence at the crossing location at the time of construction
- geotechnical issues, including HDD feasibility, the stability of the valley slopes and the risk of debris flow
- hydrotechnical issues such as flow volumes and channel stability
- construction issues, including complexity, risk, safety, schedule and cost
- regulator, resource managers, Aboriginal group, community and stakeholder input
- temporary and permanent access requirements
- pipeline operational and pipeline integrity issues
- reliability, robustness, cost and maintenance issues over the life of the pipelines

Discussions regarding watercourse crossings are ongoing with representatives from the Department of Fisheries and Oceans Canada, Transport Canada, provincial agencies, Aboriginal groups, local communities and interest groups.

6.2 Watercourse Crossing Methods

The following sections describe the watercourse crossing methods that will be used for the Project. For a description of the mitigation measures typically associated with each method, see the Construction EPMP (Volume 7A).

6.2.1 Open Cut

Open-cut crossings allow for excavation of the pipeline trench through a frozen, dry or wet channel with no requirement to separate the flow in the construction area from the rest of the channel. Flow is not interrupted. This method is often used for smaller watercourses, where there are no fisheries or water-quality considerations for watercourses that are dry or frozen to the bottom during construction, or for large watercourses where other crossing methods are not preferred. Appendix G.1, Figure G-1 shows a typical open cut crossing.

6.2.2 Isolation Methods

Isolation techniques, including dam and pump, flume, and superflume, are intended to separate the construction zone from the main flow of the watercourse and maintain clean downstream flow. The intent of these methods is to inhibit stream flow from entering the construction zone by conveying flows by pumping around or fluming through the construction zone. This is accomplished by installing upstream and downstream dams or curtains across the excavation. Isolations are often used for small or medium sized watercourses where there are fisheries, water quality or constructability considerations. Appendix G.1, Figures G-2 and G-3 show a typical dam and pump, and flume crossing, respectively.

6.2.3 Trenchless Methods

Trenchless installations are a collection of crossing techniques, described in Sections 6.2.3.1 to 6.2.3.4, that are intended to pass under or over the watercourse, thus resulting in reduced or no disturbance to the channel, banks and riparian areas. Trenchless installations are used for medium to large watercourses where there are high fisheries sensitivities, construction issues or technical considerations that preclude other, simpler methods.

6.2.3.1 Bore

A bore installation involves the excavation of bellholes on either side of the watercourse, to enable a boring machine to drill a horizontal path for the pipeline under the scour depth of the channel. In most instances, a casing is used to stabilize the path prior to pulling the pipe through. A bore crossing is typically limited to watercourses less than 100 m in width and is dependent on soil conditions and suitable staging areas on either side of the channel. An alternative crossing method is also identified in the event that the bore is determined to be not feasible, or is unsuccessful. Appendix G.1, Figure G-4 shows a typical bored crossing.

6.2.3.2 Horizontal Directional Drilling

An HDD installation is constructed using highly specialized equipment to drill a long, deep path underneath the watercourse and to pull the pipe back through. This method can be used for large watercourse crossings, but depends on the type of substrate and geometry of the valley. Extensive geotechnical investigations are required to determine the feasibility of HDD at each watercourse crossing. An alternative crossing method is also identified if HDD is determined to be not feasible, or is unsuccessful. Appendix G.1, Figure G-5a and Figure G-5b show a typical HDD crossing.

6.2.3.3 Aerial

An aerial crossing requires construction of a bridge or a supporting structure to carry the pipe over the watercourse. It is preferred at crossings where other methods are not feasible due to geometric conditions such as steep, narrow ravines.

6.2.3.4 Other Trenchless

Other trenchless methods, including micro-tunnelling, are considered for crossings where an HDD crossing is not feasible and where fisheries or other considerations preclude a trenched crossing. A micro-tunnel is constructed using a highly specialized boring machine to create a small tunnel under the watercourse to install the pipe.

6.3 Watercourse Crossing Method Selection

To facilitate the watercourse crossing selection process, a fish and fish habitat risk management framework (RMF) was developed. This is a refinement of the framework proposed by Fisheries and Oceans Canada (DFO) in the Practitioners Guide to the Risk Management Framework for DFO Habitat Management Staff Version 1.0. The RMF borrows from the methods described in Pipeline Associated Watercourse Crossings – 3rd edition by the Canadian Association of Petroleum Producers (CAPP), and refines them by using the specific biophysical features of each watercourse to determine the sensitivity of habitat and the proposed construction methods to establish the scale of negative effects[1]. This allows the risk associated with each crossing to be categorized after consideration of the site-specific crossing methods and incorporation of standardized and project-specific mitigation measures.

The RMF is designed as an iterative process for relocating crossings, revising crossing techniques and modifying mitigation measures. This approach fulfills the relocate, redesign and mitigation requirements of the Policy for the Management of Fish Habitat (DFO 1986). The residual risk can then be managed through additional mitigation (e.g., best practices), if appropriate and possible, or habitat compensation. For a detailed description of the RMF see Volume 6A, Section 11.5.2.3.

As a component of the RMF, the fish and fish habitat sensitivity was a key parameter in the method selection process at each pipeline watercourse crossing. This process was conducted in two stages: an initial screening process and a detailed site review.

6.3.1 Stage 1: Initial Screening Process

The first stage, an initial screening process, determined the proposed crossing method for watercourses that meet all of the following threshold conditions:

- low or medium fish and fish habitat sensitivity
- flow rate of less than 1.5 m^3/s expected at the time of construction
- channel width of less than 10 m
- no significant engineering or constructability issues

The decision flowchart for this initial screening process is shown in Appendix G.1, Figure G-6.

The proposed crossing methods for watercourses that are below these threshold conditions are open cut and isolation. In addition, many of these watercourses may be dry or frozen at the time of construction in which case the proposed method will be open cut.

[1] Scale of negative effects is the term used by DFO for a process that summarizes likely outcomes of a development activity.

Of the 773 identified watercourse crossings, 690 of the crossings met these threshold conditions and had no other significant issues identified.

6.3.2 Stage 2: Detailed Site Review

The second stage of the selection process entailed a detailed site review of the remaining 83 of 773 identified watercourse crossings. These crossings have potential issues and constraints related to one or more of the following areas:

- environmental
- engineering
- geotechnical
- hydrotechnical
- constructability
- operability
- cost

The proposed crossing method for these review sites was initially based on the following general guidelines (see Pipeline Watercourse Decision Flowchart Stage 2 – Review Sites, Appendix G.1, Figure G-7):

- Prefer a trenched crossing (i.e., open cut or isolated) where there is a history of successful crossings without major permitting issues or environmental effects.
- Prefer HDD crossings for the large watercourses (for widths greater than 100 m) with high fisheries sensitivity.
- Prefer bore crossings for medium-sized watercourses (for widths between 10 m and 100 m) with high fisheries sensitivity.
- Prefer isolation for smaller crossings (for widths of less than 10 m and flow of less than 3 m^3/s during construction).
- Prefer aerial only where geometrical constraints preclude other crossing methods.
- Trenchless methods will have an isolated or open cut alternative crossing method, unless fisheries or other considerations preclude a trenched crossing method.
- HDD and bore crossings will be subject to detailed engineering analyses to confirm technical feasibility (geotechnical, constructability, operations).
- The crossing method at the currently proposed HDD and bore crossings may be revised to the current alternative crossing method (isolated or open cut) if, during detailed engineering, detailed site assessment and proposed mitigation at the crossing location determines that an isolated or open cut crossing can be completed without high fisheries risk *or* that constructability or technical risks of the trenchless method are substantially higher than the trenched alternative method.

The proposed crossing method for each review site was further refined taking into account the results of the fish and fish habitat RMF as well as additional studies, fieldwork, regulatory discussions and consultations. The current proposed crossing methods for the review sites are summarized in Appendix G.1, Table G-1. At all the HDD and bore trenchless crossings, an alternative crossing method and timing of construction is also identified.

Currently, trenchless is the proposed crossing method at 33 of the review sites:

- HDD crossings at 10 sites
- bore crossings at 19 sites
- aerial crossings at 4 sites

The crossing methods and timing for all of the review sites will be finalized during detailed engineering.

Preliminary HDD feasibility assessment reports are being finalized for the Pembina River, Athabasca River, Smoky River, Wapiti River, Hook Creek, Parsnip River, Stuart River, Morice River, Hunter Creek and Wedeene River. When completed, these reports will be filed (as an update) with the NEB, as Appendix G.2 of this volume, and provided to DFO.

6.4 Vehicle and Equipment Crossings

Vehicle and equipment watercourse crossings will be needed along the RoW and the temporary and permanent access roads will be used during construction and operations.

The most suitable method for a vehicle and equipment watercourse crossing considers the following factors:

- frozen versus non-frozen conditions at the time of construction
- fish and fish habitat sensitivity
- approach gradient
- width of crossing
- temporary versus permanent use
- flow and volume

The following methods will be used for vehicle and equipment crossings of watercourses:

- snow/ice bridges
- closed culverts
- open culverts
- temporary and permanent bridges
- fords

Appendix G.1, Figures G-8 to G-11 show typical access road crossing methods for a snow fill, ice bridge, culvert and temporary bridge, respectively.

Each access road crossing of a watercourse will be assessed for site conditions expected at the time of construction. The crossing method selected, construction and corresponding mitigation measures will follow DFO operational statements and provincial guidelines and best practices, where practical. Otherwise, the appropriate provincial and federal agencies will be consulted beforehand for the necessary approvals and authorizations.

7 Clore and Hoult Tunnels

7.1 General Description

Two tunnels will be constructed through the Coast Mountains, approximately 50 km northeast of Kitimat. The tunnels will be located between the Clore River valley (KP 1072.9) on the east side of North Hope Peak and the Hoult Creek valley (KP 1086.8) on the west side of Nimbus Mountain (see Appendix C, Figure C-13). The east tunnel is referred to as the Clore tunnel and the west tunnel is referred to as the Hoult tunnel.

The tunnels will provide greatly enhanced pipeline stability and safety, and reduced RoW reclamation and restoration activities relative to conventional pipeline design and construction in the upper reaches of the Clore River and Hoult Creek valleys.

The Clore and Hoult tunnels will be approximately 6.5 km and 6.6 km long, respectively, with both tunnel inverts set at an elevation of between 700 and 800 m above sea level. The floor of each tunnel will be near horizontal with a slight grade to drain seepage water toward the portals.

The tunnels will be approximately 5.5 m high and 5.5 m wide in cross-section. These dimensions provide sufficient space for the oil and condensate pipelines, ventilation ducts and other utility lines, construction equipment, and pipeline inspection and maintenance equipment.

The tunnels will be designed to provide inspection and maintenance crews with year-round access. Permanent tunnel supports will be installed, where needed, to provide long-term stability of the tunnel arches and walls. There will be no public access to the tunnels.

7.2 Tunnel Design

The level of engineering and geological and geotechnical investigations that have been completed to date are considered adequate to support conceptual tunnel design and construction planning. The primary considerations that will be addressed during detailed investigation and engineering are expected to include:

- additional characterization of the rock mass quality and groundwater conditions expected to be encountered during construction
- evaluation of tunnel lining needs for long-term integrity and safety for the pipelines and for operating and maintenance activities
- development of detailed mitigation measures for control and treatment of seepage water during and following construction

7.3 Construction

The tunnels will be constructed using tunnel boring machines (TBMs), drilling and blasting methods or a combination of both methods. For the tunnel boring option, two TBMs will be used, one for each tunnel. The TBMs will operate simultaneously to excavate the majority of each tunnel, working from the central portal area between the two tunnels. Some drill and blast work will also be used to support the TBM option and create a starter tunnel. For the drill and blast option, the tunnels will be constructed using simultaneous excavation from the four tunnel portals.

A powerline may be installed to the central portal area to provide power for the TBMs if the TBM method is selected.

Contractors will likely operate three 8-hour shifts per day, seven days per week. Tunnel construction, including access road development and pipe installation is scheduled to take approximately 36 months subject to rock conditions and productivity rates.

Some overburden soils or highly weathered rock is expected in the tunnel portal areas. Tunnel portal construction is expected to involve open cuts in soil and rock, with excavation side slopes being cut back to stable angles or supported by shotcrete and ground anchors.

Both tunnels will be constructed primarily in rock. For the preliminary geotechnical assessment of anticipated tunnelling conditions, see Section 3.2 and Appendix E, Report E-2.

Rock conditions appear to be favourable for tunnelling. There will be some areas within and adjacent to fault zones where sheared and broken rock is expected. The tunnels will be constructed through these areas using standard construction methods and ground support techniques. Additional ground support will be installed in these areas to ensure long term stability.

For tunnels that are constructed by drilling and blasting, it is conventional construction practice in sound rock to have a single excavation and support cycle completed each shift. Slower progress is expected in poorer rock conditions.

Tunnel support needs will vary with the quality of the rock encountered during construction and will typically range from localized rock bolts in locations with high rock quality to heavy ground support consisting of pattern bolting with steel sets and shotcrete lining in sections with very poor rock quality.

It is possible that high-pressure water bearing zones will be encountered in some fault zones during tunnel construction. Probe holes will be drilled ahead of the tunnel face to detect the presence of high-pressure water bearing zones so that they can be grouted before excavation.

Construction of the two tunnels will generate about 400,000 m^3 of waste rock (including an allowance for bulking). An excess cut disposal area (waste rock disposal) of about 20 ha will be located near each tunnel portal. Potential excess cut disposal areas have been identified near each tunnel portal and will be confirmed during detailed engineering once the portal locations have been finalized.

Permanent access roads will be constructed to the tunnel portals for use during construction and operations.

A communication infrastructure will be established for construction that will include temporary radio networks, satellite and cell phone communication.

7.4 Construction Logistics

Three construction camps will be needed for the contractor crews and project support personnel:

- One camp will be located in the Clore River valley near the east portal of the Clore tunnel. This camp will support tunnel construction from the east portal of the Clore tunnel.
- A second camp will be located in a tributary valley of the Clore River, near the west portal of the Clore tunnel. This camp will support tunnel construction from the west portal of the Clore tunnel and the east portal of the Hoult tunnel.
- The third camp will be located in the Hoult Creek valley near the west portal of the Hoult tunnel to support tunnel construction from that portal.

Existing forest service roads will provide access to the Clore tributary valley and Hoult Creek. These roads will be upgraded at some locations to meet tunnel construction needs, including increasing the width of the road in some locations and upgrading or replacing some bridges and culverts. A new access road will carry construction traffic from existing logging roads in the Gosnell Creek valley to the east portal of the Clore tunnel. Access to the tunnel portals will entail construction of temporary bridges at the east and the west portals of the Clore tunnel and at the west portal of the Hoult tunnel.

Construction of the tunnels will likely be ongoing over three years. Snowfall near the tunnels is heavy and there are a number of avalanche prone slopes in the area. The tunnel portal locations have been selected to avoid direct avalanche issues. Some sections of the construction access roads and some work areas, particularly in the Clore tributary valley and the Hoult Creek valley are exposed to avalanches. A program to address avalanche issues during the winter seasons will be implemented under the direction of certified avalanche technicians, who will be based in the construction camps.

The three construction camps will be located near the portals to provide accommodation for workers during tunnel construction. Construction camps and most work areas will be located in areas that are safe from avalanche issues.

7.5 Acid Rock Drainage

Preliminary drill holes and other information indicate that the rock formations that will be encountered along the current proposed tunnel alignment are generally not potentially acid generating. However, it is possible that localized zones of potential acid generating rocks will be encountered during tunnel excavation.

Additional detailed investigations, including geochemical testing of rocks and groundwater, will be undertaken during detailed engineering to provide a more reliable assessment of the potential sources and concentrations of contamination that may be generated during and following tunnel construction. However, because of the limitations associated with subsurface investigations of tunnels at this depth, the selection and design of mitigation measures will be based on actual conditions encountered during tunnel excavation.

Monitoring for the presence of acid generating rocks will be undertaken during tunnel excavation. Mitigation plans for controlling acid rock drainage from the tunnel and from the excess cut disposal areas, both during and following tunnel construction, will be implemented as needed (see Appendix E, Report E-1-1). Typical mitigation measures for acid generating rock include:

- avoidance, where possible
- disposal in designated areas where oxidation will be avoided (capped or under water)
- mixing with buffer material
- shotcreting of bedrock surfaces

8 Pump Stations

8.1 General

The oil pipeline will have seven pump stations, including the initiating pump station at the Bruderheim Station. The condensate pipeline will have nine pump stations, including the initiating pump station at the Kitimat Terminal. For the pipeline system flow diagram, see Appendix H, Figure H-1.

There will be intermediate pump stations at eight locations along the pipeline route. Six of these locations (Whitecourt, Smoky River, Tumbler Ridge, Bear Lake, Fort St. James and Burns Lake) will have pumps for the oil pipeline and the condensate pipeline. Two of these locations (Houston and Clearwater) will only have pumps for the condensate pipeline.

Conceptual plot plans for each of the pump stations, with the exception of the condensate initiating station contained within the Kitimat Terminal, are presented in Appendix H (see Figures H-2 to H-10). Each intermediate pump station will occupy an area of approximately 4 ha, including a buffer zone and firebreaks. The Bruderheim Station will occupy an area of approximately 2 ha. For the process flow diagrams (PFDs) for each pump station, see Appendix H, Figures H-11 to H-26. For the plans and diagrams for the condensate initiating station, see Appendix I.

The preliminary station design and conceptual plot plans are intended to illustrate the major components of each station. Automated pump station bypass assemblies will be installed at intermediate oil pump stations to facilitate batch separation operations. The station design and actual layout of each station will be finalized during detailed engineering once final design parameters and site-specific data are available.

Each pump station will have numerous safety standard measures incorporated into its design to eliminate accidents and malfunctions or reduce their severity. This will be supported by:

- remote monitoring
- well trained personnel who will visit each site on a regular basis
- appropriate maintenance and operational procedures for the safety and integrity of the facility

The planned safety measures for each pump station are included in the description of the various systems described in this section.

8.2 Civil Infrastructure

Engineered containment berms will be constructed around the perimeter of each site to prevent surface runoff from flowing off site and to contain any hydrocarbons. The area inside the diversion berms will be graded so that surface runoff will collect in a lined containment pond. The capacity of the containment pond will be approximately 1,600 m^3 (10,000 bbl). The water in the containment pond will be tested and treated as necessary before being discharged off site.

Each pump station will also have the following infrastructure components:

- a site access road from the nearest public road
- site fencing, including access gates
- a parking area
- power supply lines

8.3 Pumps and Motors

Electrically powered centrifugal pumps, connected in series, will be used for the oil and condensate pipelines, as indicated on the conceptual plot plans. The requirement for flow recirculation lines, that could maintain minimum flow at start up and allow for throughput volumes below the design values, will be further evaluated during detailed engineering.

The number and horsepower of the pumps at each station to achieve the average annual capacity in the oil and condensate pipelines was determined during the hydraulic analyses (see Section 4).

The anticipated number of pumps and the associated electrical power at each station are summarized below (see Table 8-1) and will be finalized during detailed engineering.

Table 8-1 Summary of Pumps and Motor Size

	Approximate Kilometre Post	Purpose	Oil Pumps[a] and Motor Size	Condensate Pumps[b] and Motor Size
Bruderheim	0	Oil	6 @ 4,290 KW (5,750 HP)	N/A
Whitecourt	203.2	Oil and Condensate	5 @ 4,290 KW (5,750 HP)	2 @ 4,290KW (5,750 HP)
Smoky River	400.6	Oil and Condensate	5 @ 4,290 KW (5,750 HP)	2 @ 4,290 KW (5,750 HP)
Tumbler Ridge	598.1	Oil and Condensate	3 @ 4,290 KW (5,750 HP)	2 @ 4,290 KW (5,750 HP)
Bear Lake	716.0	Oil and Condensate	2 @ 4,290 KW (5,750 HP)	2 @ 4,290 KW (5,750 HP)
Fort St. James	824.5	Oil and Condensate	3 @ 4,290 KW (5,750 HP)	2 @ 4,290 KW (5,750 HP)
Burns Lake	925.5	Oil and Condensate	3 @ 4,290 KW (5,750 HP)	2 @ 4,290 KW (5,750 HP)
Houston	1002.0	Condensate	N/A	2 @ 4,290 KW (5,750 HP)
Clearwater	1124.7	Condensate	N/A	2 @ 4,290 KW (5,750 HP)

Table 8-1 Summary of Pumps and Motor Size (cont'd)

	Approximate Kilometre Post	Purpose	Oil Pumps[a] and Motor Size	Condensate Pumps[b] and Motor Size
Kitimat	1172.2	Condensate	N/A	2 @ 4,290 KW (5,750 HP)

NOTES:
[a] Number of oil pumps includes one installed spare at Bruderheim.
[b] Number of condensate pumps includes one spare at each of the following stations: Tumbler Ridge, Fort St. James, Burns Lake, Houston and Kitimat.
HP – horsepower
N/A — not applicable

Each pump station will be controlled using a variable-frequency drive (VFD) system. Each pump station will have a VFD that will supply a soft start for the pump motors and provide primary station pressure control.

The stations will also have pressure control valves (PCVs) on the discharge side. The PCVs will provide secondary station pressure control. The need for additional VFDs at the initiating and other stations will be determined during detailed engineering. If the VFD system implemented in final design is considered suitably reliable, the PCVs used to provide secondary station control might be eliminated, subject to other operational considerations.

The pumphouse buildings will be enclosed structures with concrete floors.

8.4 Electrical Systems

Powerlines will be constructed to supply electrical power for the pump stations. These powerlines will connect to existing transmission systems operated by various utility companies such as ATCO Power, AltaLink and BC Hydro. In British Columbia, Northern Gateway will be responsible for supplying connection facilities to BC Hydro, and in Alberta, the utility providers will supply the connection facilities. Provision for substations are included for each pump station.

Electrical services buildings will house medium-voltage equipment for pump motors, 480-V motor control centres, VFDs, the control system and miscellaneous equipment. Modifications to the electrical system will be considered during detailed engineering, which may eliminate the need for 5 kV motor control centre's (MCC) while still maintaining the safety and reliability of the pump station.

The potential need for uninterruptable power supply (UPS) and backup generators will be evaluated during detailed engineering. The electrical services buildings will be modular units with the electrical equipment pre-installed and wired prior to shipment to site.

The electrical system will be designed to enable the medium-voltage motor busses and the 480-V utility busses to be isolated without affecting each other.

Where needed, the UPS systems, including backup generators will be designed to maintain critical control in the event of the loss of primary electrical supply.

8.5 Piping

Oil and condensate piping at the pump stations will be designed in accordance with the design criteria (see Table 8-2).

Table 8-2 Design Criteria for Pump Stations

Item	Oil Piping	Condensate Piping
Pipe size	914 mm OD (NPS 36)	508 mm OD (NPS 20)
Design pressure	14,900 kPa (2,160 psig)	14,900 kPa (2,160 psig)
Pressure class	PN 150	PN 150
Design factor	0.6	0.6
Minimum design temperature	-45°C	-45°C
Maximum design temperature	50°C	50°C
Material grade	359 to 483 (MPa)	359 to 483 (MPa)

All piping will consist of low carbon, high strength, low alloy steel. It is anticipated that the wall thickness for large diameter piping (NPS 10 to NPS 36) will range from 12.7 mm to 25.4 mm. Welding specifications and procedures will be developed and welders will be qualified in accordance with CSA Z662-07.

In general, equipment and piping at the pump stations will be installed above ground. Anticipated exceptions include drain piping and road crossings within pump station limits. Corrosion control measures will include painting all equipment and facilities and enclosing them within weatherproof buildings. Cathodic protection will be provided for below grade piping and steel piles.

Thermal relief valves will be provided to protect piping and equipment connected to the oil and condensate pumps. Thermal relief valve discharges will be drained to either the oil or condensate sumps, as appropriate. The sumps will also collect fluids from equipment drains. Recovered hydrocarbon will be re-injected at the respective oil and condensate station inlets.

Scraper trap facilities, complete with automated pump station bypass headers for the oil pipeline, will be installed at the pump stations (see Section 5.6 and Appendix H, Figures H-2 to H-10). Scraper signal and hydrocarbon density instrumentation will be installed upstream of each oil pump station.

All pressure vessel and fitting designs will be registered in accordance with CSA B51-03, Boiler, Pressure Vessel, and Pressure Piping Code. All qualifying pressure vessels and fittings will be pre-designed and registered for commercial distribution in Canada. These vessels and fittings may include items such as hydraulic accumulators for valve actuators and nitrogen bottles for pressure surge relief valves.

8.6 Instrumentation

The following instrumentation and controls will be provided for each pump station:

- computer-based control system
- ultrasonic flow meter for the material balance system (MBS)
- V-cone meters on recirculation lines
- pressure control valve/flow control valve
- pressure recorder
- pressure transmitters
- temperature transmitters
- leak detection
- sump level transmitter (radar) and level switches
- heated instrument enclosures
- communications land line
- backup satellite or radio communications, where required

The electrical services buildings at each pump station will have heat detectors and smoke detectors to detect fires arising from electrical faults or overheating of electrical equipment. Gas detectors will also be installed to monitor for hydrocarbon leaks.

Infrastructure, including radio communication towers, associated with the selected communication systems, will be determined during detailed engineering.

The pumphouse building at each pump station and the individual pump motor units will be equipped to detect the presence of hydrocarbon gases and heat or flames.

The pump station sites will be designed with emergency shutdown systems, including manually operated emergency shutdown stations.

8.7 Buildings

Various buildings will be needed for the pump stations (see Table 8-3). The building requirements, including the need for pumphouses, will be evaluated and finalized during detailed engineering. The need for additional VFDs will also be determined during detailed engineering and may affect the size and number of buildings at each pump station.

All pump stations will be provided with office space, workshop space and restroom facilities. These will be further defined during detailed engineering.

Table 8-3 Proposed Buildings for the Pump Stations

Building Description	Size (m)	Quantity	Location (Pump Station/Valve Site)
Pumphouse	25.8 x 54.6 x 8.0	1	Bruderheim
Electrical Services Building (ESB)	11 x 16.75 x 4.2	2	Bruderheim
Hazardous Storage	3.0 x 4.0 x 3.0	1	Bruderheim
Pumphouse	25.8 x 54.6 x 8.0	1	Whitecourt
ESB	11.0 x 16.75 x 4.2	3	Whitecourt
Hazardous Storage	3.0 x 4.0 x 3.0	1	Whitecourt
Pumphouse	25.8 x 68.1 x 8.0	1	Smoky River
ESB	11.0 x 16.75 x 4.2	3	Smoky River
Hazardous Storage	3.0 x 4.0 x 3.0	1	Smoky River
Pumphouse	25.8 x 54.6 x 8.0	1	Tumbler Ridge
ESB	11.0 x 16.75 x 4.2	2	Tumbler Ridge
Hazardous Storage	3.0 x 4.0 x 3.0	1	Tumbler Ridge
Pumphouse	25.8 x 54.6 x 8.0	1	Bear Lake
ESB	11.0 x 16.75 x 4.2	2	Bear Lake
Hazardous Storage	3.0 x 4.0 x 3.0	1	Bear Lake
Pumphouse	25.8 x 68.1 x 8.0	1	Fort St. James
ESB	11.0 x 16.75 x 4.2	2	Fort St. James
Hazardous Storage	3.0 x 4.0 x 3.0	1	Fort St. James
Pumphouse	25.8 x 54.6 x 8.0	1	Burns Lake
ESB	11.0 x 16.75 x 4.2	2	Burns Lake
Hazardous Storage	3.0 x 4.0 x 3.0	1	Burns Lake
TPumphouse	16.2 x 22.6 x 8.0	1	Houston
ESB	11.0 x 16.75 x 4.2	1	Houston
Hazardous Storage	3.0 x 4.0 x 3.0	1	Houston
Pumphouse	16.2 x 33.6 x 8.0	1	Clearwater
ESB	11.0 x 16.75 x 4.2	1	Clearwater
Hazardous Storage	3.0 x 4.0 x 3.0	1	Clearwater

9 Kitimat Terminal

The Kitimat Terminal will be located on the west side of the Kitimat Arm (see Appendix C, Figure C-14). It will consist of land-based facilities (the tank terminal) and marine facilities (the marine terminal). The Kitimat Terminal will occupy a land area of approximately 220 ha.

The Kitimat Terminal has two primary functions:

- to receive oil transported by the oil pipeline from the Bruderheim Station, transfer it to tanks and then load it into tankers
- to unload condensate from tankers, transfer it to tanks and then transfer it into the condensate pipeline for transport to the Bruderheim Station
- The Kitimat Terminal will consist of the following major facilities:
    - a tank terminal including:
        - 11 oil tanks and 3 condensate tanks
        - hydrocarbon transfer systems, including custody transfer metering
        - a remote impoundment reservoir
        - oil receiving facilities
        - an initiating condensate pump station
        - associated infrastructure
    - a marine terminal including two tanker berths, one utility berth and associated infrastructure

See Appendix I, Figures I-1 and I-2 for a conceptual layout of the Kitimat Terminal. See Figures I-3 to I-18 for PFDs of the oil and condensate systems. See Figures I-19 to I-24 for the Kitimat Terminal plan and profiles. See Figures I-25 and I-26 for the conceptual layout and profile of the marine terminal.

This section includes a description of the various terminal components, including their preliminary design and a description of their operation. The Kitimat Terminal design will be finalized during detailed engineering once final design parameters and site specific data are available.

The Kitimat Terminal has numerous safety measures incorporated into its design to eliminate accidents and malfunctions or reduce their severity. This will be supported by well trained personnel, appropriate maintenance and operational procedures for the safety and integrity of the facility. The planned safety measures for the terminal are included in the description of the various systems described in this section.

9.1 Oil Transfer System

9.1.1 System Overview

The oil transfer system facilities at the Kitimat Terminal will be designed to receive and segregate batches of oil from the Bruderheim Station and direct these batches to the appropriate tanks. From the tanks, the oil will flow by gravity pipeline through the custody transfer metering systems, located near the tanker berths, to the outlet of the loading arms for transfer to the tankers. See Appendix I, Figures I-4 to I-8 and I-13 and I-14 for the oil transfer system PFDs.

9.1.2 Oil Receiving Station

A pressure letdown station, consisting of pressure control valves, will reduce the oil pressure before it is transferred to the tanks. The piping and equipment will be protected by pressure relief valves, which will be connected by piping to the oil tanks.

9.1.3 Oil Tanks

The oil receiving station will direct the hydrocarbons to the oil tank valve manifold. The manifold will be designed to simultaneously allow receipt of oil from the pipeline, delivery of oil to the tankers and transfer of oil between the tanks. The manifold will be designed to provide isolated, segregated flow paths for the various operations.

Initially, 11 oil tanks will be installed at the Kitimat Terminal. The terminal site will be developed to accommodate two potential additional tanks for hydrocarbon segregation.

For the oil tank specifications, see Table 9-1. The size and spacing of the tanks will be optimized during detailed engineering.

Table 9-1 Oil Tank Specifications

Item	Metric Units	Imperial Units
Tank diameter	74.07 m	243 ft.
Tank height	18.29 m	60 ft.
Roof type	Open-top external floating pontoon	
Minimum freeboard	1 m	3.3 ft.
Nominal capacity per tank	78,800 m^3	496,000 bbl
Working capacity per tank	67,700 m^3	426,000 bbl
Total working capacity for 11 tanks	744,100 m^3	4,680,000 bbl
Design injection flow rate per tank	92,700 m^3/d	583,000 bbl/d
Average takeaway flow rate per tank	190,800 m^3/d	1,200,000 bbl/d

The floating roofs on the tanks will be equipped with mechanical shoes and secondary seals to limit hydrocarbon vapour emissions. The roofs will be designed to sustain unbalanced snow loads and will have adequate drainage to accommodate heavy rainfall.

Each tank will be equipped with a radar tank level gauge, pressure transmitters and temperature sensor that can be monitored on displays at the Kitimat Control Centre and the Edmonton Control Centre (see Section 11 for further information about the control centres). Tank levels and temperature data will be sent to inventory management software at the Edmonton Control Centre.

Tank overfill protection will be provided by high-level switches that will trigger alarm sequences in the event that the primary level monitoring system fails. The tanks will be designed with a minimum freeboard of 1 m.

The inline transfer pumps will be used to move oil between tanks. One inline pump will serve as a backup to the main pump.

Tank Safety Design

Tanks and the supporting terminal will be designed to meet the Environmental Code of Practice for Aboveground and Underground Storage Tank systems containing Petroleum Products and Allied Petroleum Products (CCME PN 1326). Specific systems and equipment used to reduce the risks of accidents and malfunctions are described below.

Overfill Protection

All tanks will be provided with overfill protection consisting of a primary level monitoring system, and high-level switches that will trigger alarm sequences in the event that the primary level monitoring system fails. The alarms will automatically alert personnel in the control centre as well as having a visual and audible alarm for terminal and ship personnel. Activation of a tank's high-level switch alarm will also initiate closing of the tank line manifold valve, preventing further filling of the tank. The tanks will be designed with a minimum freeboard of 1 m, allowing enough time for personnel to take actions to prevent an overflow.

Due to large elevation differences between various tanks in the terminal there is the potential for hydrocarbons to flow from a higher elevation tank to a lower elevation tank. The tank valve manifold will incorporate check valves into its design to limit the ability for volumes to drain from one tank to another. All remaining piping capable of transferring oil and condensate between tanks will be equipped with isolation valves connected to an uninterruptible power supply generator.

Vapour Emissions

All tanks will be equipped with floating roofs complete with mechanical shoes and secondary seals to limit hydrocarbon vapour emissions.

Secondary Containment

All above ground tanks will have containment berms. The tank lot is supplemented by an impoundment reservoir. The reservoir will be sized for a minimum of 110% of the volume of the largest tank plus all the water collected within the area of the tanks during a peak rainfall event and an allowance for water volume needed for fire fighting.

All secondary containment facilities, including the bermed areas and the impoundment reservoir, will be double-lined with an impervious membrane liner and with a leak detection system.

The impoundment reservoir will be used to contain and manage the storm water collected in the tank terminal. It will be processed as per the site water management system described in Section 9.5.4.

Sump Tanks

All sump tanks will be double-walled tanks with an interstitial space that can be monitored. Appropriate overfill protection devices will be provided for all sump tanks.

9.1.4 Oil Loading System

Both tanker berths will have oil loading capabilities. Two 1,067-mm OD (NPS 42) oil lines will connect the tank manifold to the foreshore for simultaneous oil loading capabilities to both berths. Oil will flow by gravity from the tanks through the berths to the moored tankers (see Appendix I, Figure I-1).

A vapour recovery unit (VRU) system is included in the preliminary design, as further described in Section 9.5.

The loading headers and loading arms will be used for loading oil to the tankers at a maximum design rate of 15,900 m^3/h (100,000 bbl/h) at each loading berth.

Loading arms will be attached to the tanker's valves by means of hydraulically actuated mechanical flange coupling connections. The loading arms will accommodate tidal fluctuations and various tanker sizes.

The loading arms will be equipped with emergency shutdown valves, cameras and hydraulic systems for the manipulation of the arm positions.

Piping from the downstream metering isolation valve up to and including the loading arms will be designed in accordance with American Society of Mechanical Engineers (ASME) B31.3, Process Piping Code.

9.1.5 Custody Transfer Metering

Two custody transfer metering skids will be installed near the north tanker berth (see Appendix I, Figure I-1). Metering equipment will include:

- flow meters
- block valves
- back pressure control valves
- pressure transmitters
- temperature transmitters
- strainers
- bi-directional meter provers (calibrators)
- check valves
- flow control valves

The 406-mm OD (NPS 16) positive displacement meters will measure custody transfers. Each metering skid will house 11 flow meters and can handle the design loading rate of 15,900 m^3/h (100,000 bbl/h). The combined capacity of the two metering skids is 31,800 m^3/h (200,000 bbl/h). Either inline spare meters or warehouse spares will be provided. Cross-over piping will be provided to allow oil flow to either metering skid.

The meter in-service limits of error will be within the range of ±0.25%. The metering station will be equipped with a computer-controlled flow management system consisting of main and backup flow computers, remote terminal units and peripheral equipment. The station will have the instrumentation, electrical wiring, conduit, manifolds, pipe and fittings for a complete remotely controlled measurement system.

Meter proving and quality assurance tests will be performed periodically. A quality assurance building will be provided for the oil delivery line. The quality assurance building will contain the following items:

- a sampling system
- a custody transfer service densitometer
- a viscometer
- various temperature, pressure and flow measurement instruments
- leak protection or detection

9.1.6 Recovered Oil Drain Tank

A recovered oil drain tank will be located onshore near the berths to facilitate periodic draining of the oil delivery and condensate pipelines. It will have a nominal capacity of 13,800 m^3 (87,000 bbl), sufficient to contain the volume of one oil delivery line or one foreshore delivery line to a loading berth. The large diameter pipelines in the tank terminal can also be drained into this tank, if necessary (see Appendix I, Figure I-16).

The drain tank will be equipped with two pumps to return the hydrocarbon contents of the tank back into the respective oil or condensate delivery line or the oil-water separator (see Table 9-2 for tank specifications). The tank is also tied into the site water management system (see Section 9.5.4). This tank will be equipped with similar safety features as described in Section 9.1.3.

Table 9-2 Recovered Oil Drain Tank Specifications

Item	Metric Units	Imperial Units
Tank diameter	35.1 m	115 ft.
Tank height	14.6 m	48 ft.
Roof type	Fixed Cone	Fixed Cone
Overflow protection setting	1 m	3.3 ft.
Nominal capacity per tank	13,800 m^3	87,000 bbl
Working capacity per tank	12,800 m^3	80,500 bbl
Injection flow rate per tank	7,600 m^3/d	48,000 bbl/d
Takeaway flow rate per tank	7,600 m^3/d	48,000 bbl/d

Vent lines will be installed on the delivery line, the metering station and on the delivery line downstream from the metering station. The vent lines will either be manually controlled or will incorporate a float switch valve designed to open when exposed to air and shut when exposed to liquids. This will allow for the controlled filling of the delivery pipeline while preventing liquids from entering the vent line once the pipeline is full.

Small valves bypassing the main isolation valves will be provided so that the oil delivery lines can be refilled at a controlled rate.

At the berth, two stripping pumps will be provided for draining and recycling oil from the loading arms and other piping that cannot be drained by gravity to the recovered oil drain tank.

9.1.7 Oil Operating Pressures

For the maximum operating pressures (MOPs) at various locations within the oil transfer system at the Kitimat Terminal, see Table 9-3. Surge relief systems will be provided in the tank and marine terminals to prevent pressure from rising above the piping MOP. Thermal relief will be provided on all large segments of piping that are capable of being isolated. Relief valves will protect piping to ensure that design pressures are not exceeded.

Table 9-3 Oil System Maximum Operating Pressures – Kitimat Terminal

Location	Max. Operating (kPa)[a]	Design (kPa)
Oil receiving station	13,790	14,890
Oil tank transfer pump	660	1,896
Recovered oil drain tank transfer pump	1,850	1,896
Tank terminal	580	1,896
Marine terminal	1,830	1,896
Oil custody transfer meter	580	1,896

NOTE:
[a] Steady-state pressures based on normal operating flow rates.

For the outside diameters and classes of the large diameter piping for the oil transfer system at the Kitimat Terminal, including both berths and the interconnection between the tank terminal and the marine terminal, see Table 9-4.

Table 9-4 Oil System Outside Diameter and Class – Kitimat Terminal

Location	Number of Lines	Outside Diameter (mm)	Nominal Pipe Size	Piping Class	Pipe Wall Thickness (mm)	Pipe Material
Pressure regulating valves (one operating, one spare)	2	610	24	PN 150	15.9	CSA Gr 448
Receiving station to delivery manifolds	1	762	30	PN 20	9.52	CSA Gr 241
Tank transfer header	1	610	24	PN 20	9.52	CSA Gr 241
Tank lines	11	762	30	PN 20	9.52	CSA Gr 241
Delivering manifold to metering stations	2	1067	42	PN 20	11.9	CSA Gr 241
Metering runs	22	406	16	PN 20	9.52	CSA Gr 241
Metering stations to loading headers	2	1067	42	PN 20	19.1	ASTM A 671
Loading headers (common with condensate unloading headers)	2	1067	42	PN 20	19.1	ASTM A 671
Tanker loading arms	8[a]	508	20	PN 20	Per vendor	ASTM A-333, Gr. 6

NOTES:
[a] Four arms for each berth
CSA – Canadian Standards Association
ASTM – American Society for Testing and Materials

9.2 Condensate Transfer System

9.2.1 System Overview

The condensate transfer system at the Kitimat Terminal will be designed to receive condensate from tankers and pump it through the custody transfer metering system to the appropriate tanks. From the tanks, the condensate will be directed to the initiating condensate pump station and then pumped into the condensate pipeline for transport to the Bruderheim Station. See Appendix I, Figures I-9 to I-12 for the condensate transfer system PFDs.

The following sections provide additional information regarding the design of the condensate transfer system facilities at the Kitimat Terminal.

9.2.2 Tanker Unloading

Condensate unloading from either berth is possible but only one at a time. The condensate maximum design unloading flow rate will be 11,100 m^3 (70,000 bbl) per hour. Loading arms will attach to the tanker's manifold valves by means of hydraulically actuated mechanical coupling connections. The arms will accommodate vertical movement of the tankers due to tidal fluctuations.

Shipboard pumps will unload condensate from the tankers. The condensate will flow into a condensate and vapour separator to remove any vapour slugs. The separator will be equipped with instrumentation to monitor the liquid level and pressure of the condensate.

Condensate will flow from the separator to a quality assurance building and then to the custody transfer metering station.

Shipboard pumps will not normally have the capacity to pump condensate volumes up to the tank lot, which will be approximately 180 m above the elevation of the foreshore facilities. Accordingly, the condensate will flow from the metering system into a 914-mm OD (NPS 36) pipeline and be pumped up to the condensate tanks by two, 3,000-kW (4,000-HP) pumps located near the tanker berths. A third pump will be provided as a backup, and all three pumps will be connected to a recirculation line to assist in the controlling flow rate.

Pressure relief upstream of the condensate unloading booster pumps will not be needed because shipboard pumps are not capable of operating at pressures above the piping MOP.

Piping from the loading arms up to the upstream metering facility isolation valve will be designed in accordance with ASME B31.3.

The condensate unloading arms will be equipped with an emergency shutdown system, cameras and hydraulic systems for the manipulation of the arm positions.

9.2.3 Custody Transfer Metering

The custody transfer metering skid for condensate will be installed near the north tanker berth (see Appendix I, Figure I-1). The metering skid will be similar in most respects to that described for the oil transfer system (see Section 9.1.5). It will have six 323.8-mm (NPS 12) turbine custody transfer meters (five operating, one in-line spare) that will handle the design loading rate of 11,100 m^3 (70,000 bbl) per hour.

9.2.4 Condensate Tanks

Three condensate tanks will be located at the Kitimat Terminal (see Table 9-5 for the tank specifications). The size and spacing of the tanks will be optimized during detailed engineering.

Two sump tanks will be provided near the main terminal operations area. One sump tank will be located near the tanks and will collect condensate from equipment drains in that area. A second sump tank near the condensate scraper trap will collect condensate from the trap and other maintenance drains in the area. Both sump tanks will pump the recovered condensate into the main condensate tanks.

Vent piping lines will be provided, as necessary, so that the delivery lines can be drained and refilled for maintenance.

The condensate tanks will be equipped with similar safety features as described in Section 9.1.3.

Table 9-5 Condensate Tank Specifications

Tank Specifications	Metric Units	Imperial Units
Diameter	74.07 m	243 ft.
Height	18.29 m	60 ft.
Roof type	Open-top external floating pontoon	
Overflow protection setting	1 m	3.3 ft.
Nominal capacity per tank	78,800 m^3	496,000 bbl
Working capacity per tank	67,700 m^3	426,000 bbl
Total working capacity for 3 tanks	203,100 m^3	1,280,000 bbl
Injection flow rate per tank	133,500 m^3/d	840,000 bbl/d
Takeaway flow rate per tank	34,100 m^3/d	214,000 bbl/d

9.2.5 Condensate Initiating Pump Station

The initiating condensate pump station will be located within the main terminal operations area and will be equipped with two pipeline pumps. Scraper trap facilities will also be installed at the Kitimat Terminal for the condensate pipeline (see Section 5.6).

9.2.6 Condensate Operating Pressures

For the MOPs at various locations within the condensate transfer system at the Kitimat Terminal, see Table 9-6. Surge relief systems will be provided in the marine terminal downstream of the unloading booster pumps to prevent pressure from rising above the piping MOP. Thermal relief will be provided on all large segments of piping that are capable of being isolated. Relief valves will protect piping to ensure that design pressures are not exceeded.

Table 9-6 Condensate System Maximum Operating Pressures – Kitimat Terminal

Location	Max. Operating Pressure (kPa)	Design Pressure (kPa)
Marine terminal	1,829	1,896
Marine terminal to tank manifold	1,735	1,896
Tank transfer pump	520	1,896

For the outside diameters and classes of the large diameter piping for the entire condensate system at the Kitimat Terminal, including both berths and the interconnection between the tank terminal and the marine terminal, see Table 9-7.

Table 9-7 Condensate Piping System Outside Diameter and Class – Kitimat Terminal

Location	Number of Lines	Outside Diameter (mm)	Nominal Pipe Size	Piping Class	Pipe Wall Thickness (mm)	Pipe Material
Tanker unloading arms (common with oil loading arms)	8	508	20	PN 20	Per vendor	ASTM A-333, Gr. 6
Unloading header (common with oil loading headers)	2	1,067	42	PN 20	19.1	ASTM A 671
Unloading header to vapour separator	2	1,067	42	PN 20	19.1	ASTM A 671
Vapour separator to metering station	1	914	36	PN 20	19.1	ASTM A 671
Metering runs	6	324	12	PN 20	9.52	241
Marine terminal to tanks	1	914	36	PN 20	9.52	241
Tank transfer header	1	508	20	PN 20	9.52	241
Tank lines	3	610	24	PN 20	9.52	241
Tanks to pipeline	1	508	20	PN 20	9.52	241

9.2.7 Condensate Pressure Vessels

All designs for pressure vessels will be registered in accordance with CSA B51-03. One pressure vessel (condensate vapour separator) will be constructed specifically for the Project at the Kitimat Terminal. The condensate vapour separator will have a design pressure of 862 kPag (125 psig) and a volume of 44.5 m^3 (11,750 gal). All other qualifying pressure vessels or fittings are pre-designed and registered for commercial distribution in Canada. These other vessels or fittings may include, but are not necessarily limited to:

- hydraulic accumulators for valve actuators
- nitrogen bottles for pressure surge relief valves
- fabricated casings for powered inline mixers

9.3 Terminal Buildings

For a summary of the various buildings at the Kitimat Terminal, see Table 9-8. The building requirements, including the need for the initiating condensate pump station pumphouse, will be evaluated and finalized during detailed engineering.

Table 9-8 Buildings for the Kitimat Terminal

Building Description	Size (m)	Quantity	Location
Terminal Maintenance Building	24.0 x 9.5 x 5.0 H	1	Tank terminal
Pipeline Maintenance Building	53.3 x 14.6 x 6.1 H	1	Tank terminal
Control Room Building	18.0 x 25.0 x 4.0 H	1	Tank terminal
Crude Booster/Transfer Pumphouse	27.0 x 15.5 x 7.1 H	1	Tank terminal
Foam Truck Storage Building	6.0 x 6.0 x 4.0 H	1	Tank terminal
Firewater Pumphouse	11.0 x 4.7 x 5.0 H	1	Tank terminal
Firewater Transfer Pumphouse	6.5 x 6.5 x 5.0 H	1	Tank terminal
Miscellaneous Electrical Shelters	1.83 x 1.83 x 3.66 H	3	Tank terminal
Water QA Sample Buildings (WQA)	4.0 x 4.0 x 3.66 H	2	Tank terminal
Guardhouse	3.6 x 3.6 x 3.66 H	1	Tank terminal
Electrical Protection Building and Meter Building	2.0 x 3.0 x 2.4 H	2	Tank terminal
Modular Electrical Building ESB-1	7.34 x 16.76 x 3.67 H	1	Tank terminal
Modular Electrical Building ESB-2, ESB-12	3.67 x 9.1 x 3.67 H	2	Tank terminal
Modular Electrical Building ESB-3, ESB-5, ESB-6, ESB-9 and ESB-15	3.67 x 6.1 x 3.67 H	3 Crude 1 Condensate 1 Combined	Tank terminal
Modular Electrical Building ESB-7	10.97 x 16.76 x 3.67 H	1	Tank terminal
Modular Electrical Building ESB-8	7.34 x 6.1 x 3.67 H	1	Tank terminal
Modular Electrical Building ESB-11	14.7 x 16.76 x 3.67 H	1	Tank terminal
Crude Manifold Building	40.0 x 30.0 x 12.0 H	1	Tank terminal
Condensate Booster/Transfer Pumps Building	27.0 x 15.5 x 7.1 H	1	Tank terminal
Initiating Condensate Pump Station Pumphouse	54.0 x 15.5 x 7.1 H	1	Tank terminal
Condensate Manifold Building	30.0 x 24.0 x 11.0 H	1	Tank terminal
Miscellaneous Storage Building	To be defined	To be defined	Tank terminal
Office Building	22.9 x 30.5 x 7.6 H	1	Kitimat townsite
Lab and Sample Storage Building	6.5 x 6.5 x 5.0 H	1	Marine terminal
Crude and Condensate Product QA Sample Buildings (PQA)	Modular Unit Building (HVAC, Piping and Electrical Included)	3	Marine terminal
Miscellaneous Shelter: Instrumentation (IBU)	3.0 x 3.0 x 4.0 H	1	Marine terminal
Condensate Booster Pumps Building	54.0 x 30.0 x 7.1 H	1	Marine terminal
Guardhouse	3.6 x 3.6 x 3.66 H	1	Marine terminal

Table 9-8 Buildings for the Kitimat Terminal (cont'd)

Building Description	Size (m)	Quantity	Location
Control Room Building	18.0 x 25.0 x 4.0 H	1	Marine terminal
Operator Shelters	1.2 x 1.2 x 3.0 H	2	Marine terminal
Condensate Metering Building	43.0 x 20.0 x 15.0 H	1	Marine terminal
Oil Metering Building	60.0 x 30.0 x 18.0 H	1	Marine terminal
Emergency Response Equipment Storage Building	To be defined	1	Marine terminal
Foreshore Spill Response Building	To be defined	1	Marine terminal

9.4 Civil Infrastructure

The existing ground surface at the Kitimat Terminal rises steeply from the shoreline to an elevation of approximately 180 m above sea level at the tank lot. Due to the civil infrastructure work for site development, a variety of alternatives for the site layout were evaluated including:

- different tank arrangement options
- tank spacing considerations
- tank elevations to optimize the existing ground contours, optimize piping design, and reduce excess material volumes
- pipe rack routing
- location of the impoundment reservoir
- location of the tank terminal support facilities, including the substation
- arrangement of the foreshore facilities
- on-site material disposal options

The site is configured to limit earth material disposal volumes, tree logging, and overall environmental footprint while allowing for a safe, operational terminal. Site optimization activities will continue as additional site information, particularly geotechnical data, is collected.

The Kitimat Terminal is anticipated to have the following major civil infrastructure components:

- a main access road to the site, which will be an upgrade to the existing Bish Forest Service road, including bridges over waterways that do not disrupt fish habitat and that connect the terminal site to the existing public road adjacent to the Rio Tinto plant site
- site access roads within the terminal boundaries, including the marine foreshore area, the tank lot, the electrical substation, the condensate initiating pump station, and other facilities. There will be a perimeter access road around the tank terminal and access roads inside.
- a network of cut-lines and RoWs for pipe racks and cable tray raceway systems

- a site drainage and stormwater control system, which will be developed progressively as the Project moves from initial site development through construction and into the final design configuration. The system will be designed to control surface water runoff during all stages of the Project, including construction, with consideration to limit effects on the surrounding environment while maintaining the activities on site.
- a surface water drainage system to collect and direct surface water to the impoundment reservoir or to the ocean (if the oil-water concentration is less than 15 ppm) and provide surface erosion control
- a remote impoundment reservoir (see Section 9.5.3). To assist with surface water runoff during construction, the remote impoundment reservoir will be developed at an early stage of construction.
- containment berms for each of the tanks in the tank lot and for the recovered oil tank at the marine terminal (see Section 9.5.3)
- containment systems for operations that have higher potential for minor spills, such as the area around the receiving traps, the initiating station pumphouse, other hydrocarbon pumps and the maintenance areas
- a disposal site for excess civil material, which will be reclaimed and re-vegetated as part of the design
- a topsoil storage area to preserve the topsoil removed from the site for future reclamation
- site fencing, including access gates and security booths
- parking areas around the site

Additionally, a public by-pass road around the west side of the Kitimat Terminal is under consideration.

9.5 Ancillary Systems

The following ancillary systems will be provided at the Kitimat Terminal:

- electrical supply and distribution system
- fire protection system
- tank impoundment system
- site water management system
- vapour recovery unit (VRU) system
- potable water system
- utility air system
- corrosion control system
- emergency shutdown systems

9.5.1 Electrical System

A new, approximately 10 km long 287-kV transmission powerline will be constructed to supply electrical power for the terminal. This powerline will connect to the existing BC Hydro 287-kV transmission system. A 25/30-MVA main substation will also be constructed at the terminal.

The main substation will feed three medium-voltage distribution substations at appropriate locations throughout the terminal. Each distribution substation will be connected to outdoor switchgear that will feed various electrical services buildings to supply electrical power to the following components:

- the initiating condensate pump station
- the oil and condensate tanks
- the marine terminal off-loading pump station
- auxiliary equipment such as the water system for fighting fires, control rooms, maintenance shop and other facilities

Standby diesel electric generators will be installed at the Kitimat Terminal to meet essential power demands in the event of a pipeline power outage.

9.5.2 Fire Protection System

The Kitimat Terminal will be equipped with a firewater and foam system to detect and suppress any fires.

All electrical service buildings at the Kitimat Terminal will be equipped with heat detectors and smoke detectors. The initiating condensate pump station building will be equipped to detect the presence of hydrocarbon gases and heat or flames.

Fire detection will be provided at each oil and condensate tank, the custody transfer metering building and the QA building. The loading arms on the berth will be monitored with flame detectors.

Fire hydrants will be located throughout the site. For the proposed firewater and foam system PFD, see Appendix I, Figure I-3. See Table 9-9 for the fire suppression design parameters.

Table 9-9 Fire Suppression Design Parameters

Item	Capacity	
Water flow rate (including foam solution)	17,010 L/min	4,400 US gpm
Water pump discharge	1,896 kPa	275 psig
Firewater reservoir volume	5,500 m^3	1,400,000 US gal.
Total foam solution volume	90 m^3	24,000 US gal.
Total foam concentrate volume	3.8 m^3	1,000 US gal.

A firewater reservoir will provide water in case of fire and will be sized to provide a minimum of four hours of supply. There will be one electric motor driven water pump and one backup water pump driven by a diesel engine. Additional water for firefighting can be obtained from the remote impoundment reservoir.

Additionally, stand-by firewater pumps that draw seawater directly will be installed. One pump is proposed for each tanker berth. These additional pumps will serve as an emergency firewater source backup system, in case feed from the firewater reservoir is interrupted. The pumps will tie in to the main firewater distribution system at each tanker berth.

Tanks will be protected from a rim seal fire by a semi-fixed foam system. In the case of a fire, a mobile foam trailer will be connected to a foam solution connection point located outside the berms of the tank adjacent to a fire hydrant. The connection will permit foam concentrate to be blended into the water and delivered to foam distribution chambers located around the periphery of each tank roof.

The foam trailer can also be used to provide foam at any of the fire hydrants and applied using aspirating foam nozzles and hoses. The mobile foam tank trailer will have capacity for 3.8 m^3 (1,000 US gal.) of foam concentrate.

The tank terminal and marine berths will be designed in conformance with the National Fire Code of Canada (NFCC). The facility will include a firewater reservoir with a minimum of four hours supply. The system includes an operating and a backup pump for firewater distribution, both with different drivers.

Fire, Heat and Smoke Detection Systems

Appropriate fire, heat, and smoke detection systems will be provided at electrical service buildings, pump stations, ship loading arms, and various other enclosed buildings. The various instruments will provide early warning of dangerous conditions and allow time for terminal personnel to take action.

Tank Fire Protection

Tanks will be protected from a rim seal fire by a semi-fixed foam system. Firewater will be used in both foam generation and tank cooling. In the unlikely event of a fire that cannot be contained and controlled by the terminal’s fire protection system, outside resources will be contacted. The additional resources and procedures will be established in the emergency measures plan.

Marine Berth Fire Protection

The marine berths have the same fire protection system as the tank terminal, including water supply from the firewater reservoir and a foam system. In addition to the tank terminal fire system, each berth is equipped with a back-up firewater pump that can draw water from the sea in the event that water cannot be supplied by the reservoir or more than a four hour supply of water is needed. The berth firewater piping is looped and equipped with valves that will allow partial operation of the fire protection system even in the event of severe damage to a portion of the firewater piping. In addition to providing protection to the berth and mooring facilities, the fire protection system can also be used to assist in fighting a ship fire if the ship requests such intervention.

Marine Berth Fire Monitors

Both marine berths will be equipped with fire monitors (water and foam) that will be able to cover the central loading platform and berthing platforms in the event of a fire. The fire monitors will also be able to cover the immediate vicinity of the vessel’s manifold where the terminals loading arms connect to the tanker.

Under normal operations, the fire monitors will be supplied from the firewater reservoir located in the upland terminal. If the upland reservoir is not available, one seawater pump located at each berth will provide the water supply. Tugs will be able to connect into the fire monitor system and provide additional seawater.

The fire monitor system at each berth will be supplied by a ring main. Should one part of the ring main be damaged, it can be isolated so that water pressure would be maintained to the fire monitors.

9.5.3 Tank Impoundment System

The tank terminal and the recovered oil tank at the marine terminal will have containment berms; the berm wall design will be determined during detailed engineering and will likely be constructed of engineered fill or will be a vertical concrete wall system. The area inside the berms will be double-lined with an impervious membrane liner. The tank terminal berm system will be designed to allow overflow between tanks before overflow of the perimeter walls. The berm system will be designed to collect liquids and direct them through a pipe system to the remote impoundment reservoir.

A number of options were considered for the impoundment system, including a separate reservoir, local impoundment for the tanks, and a combined system across several tanks. The remote reservoir option was selected primarily for operational practicality. Given the amount of annual rainfall in the Kitimat area, any long-term collection system utilizing the bermed tank lot would affect access to the tanks for regular operations, maintenance or emergency purposes.

The remote impoundment reservoir will be located at the southwest end of the tank lot (see Appendix I, Figure I-1) at a lower elevation. The reservoir will be sized for a minimum of 110% of the volume of the largest tank plus all the water collected within the area of the tanks during a peak rainfall event and an allowance for water volume needed for fire fighting. The berms for the remote impoundment reservoir will be built of engineered fill. The reservoir will be double-lined with an impervious membrane liner with a leak detection system.

The oil and condensate tanks will be equipped with safeguards to prevent tank overflow. Each tank will have a series of level transmitters that trigger alarms when specific tank fill levels are exceeded. These alarms will initiate operator action.

The valve manifold will incorporate check valves into its design to limit the ability for oil to drain from one tank to another. All remaining piping capable of transferring oil and condensate between tanks will be equipped with isolation valves connected to an uninterruptible power supply generator.

A sump system will be located within the containment berm around the recovered oil tank at the marine terminal to collect rainwater and contact water. This sump system will deliver the collected water to the oil-water separator if instrumentation indicates that is needed. Alternatively, water from this system can be pumped to the recovered oil drain tank to separate oil from the water.

The recovered oil drain tank will be equipped with safeguards to prevent tank overflow. The tank will have a series of level transmitters that trigger alarms when various tank fill levels are exceeded. These alarms will initiate operator action.

Secondary containment for the recovered oil drain tank will be provided by direct impoundment around the tank with a berm capable of containing 110% of the volume of the tank and all the water collected from the tanker berth contact water pits.

9.5.4 Site Water Management System

The remote impoundment reservoir will contain a berm used to isolate the wet well from the rest of the pond (see Appendix I, Figure I-15). Under normal operating conditions, all water collected within the Kitimat Terminal site will be drained or pumped to the section of the pond that is segregated from the wet well. The water will then flow through an underdrain into the region encompassing the wet well. The segregated section of the pond will trap any hydrocarbon floating on top of the water while the underdrain will allow the water to flow into the region containing the wet well. Under normal operating conditions, water in the impoundment reservoir will be an accumulation of storm and surface water from the site and will have no hydrocarbon content.

Water will normally be pumped from the wet well directly into the sea. Water can also be pumped to the firewater reservoir when needed. Water leaving the wet well will be tested in-line on a continuous basis to confirm that it has a hydrocarbon content no greater than 15 parts per million (ppm) oil in water and is suitable for release to the environment. An analyzer immediately downstream of the wet-well will provide the initial test of the water quality and water with a hydrocarbon content greater than 15 ppm will be diverted and processed through an oil-water separator. Water discharged from the oil-water separator and excess water from the firewater reservoir will be tied into the main line downstream of the oil-water separator inlet. A second analyzer will be located upstream of the pipe before it discharges to the sea to provide final confirmation the water is of suitable quality. An emergency shutdown valve (ESD) will be located downstream of this analyzer for immediate isolation in the event that hydrocarbons are detected. In the event the ESD valve is closed, there is a takeoff from the pipeline, which allows the pipe to drain into the contact water collection sump. At the foreshore, the excess water will be discharged into Kitimat Arm through a submerged, perforated discharge pipe. The discharge pipe will be located away from the immediate vessel berthing area.

The oil-water separator is also connected to the recovered oil tank and contact water collection sump located on the marine foreshore. All water collected from these facilities will be processed through the oil-water separator and then discharged into the pipeline, which drains to the sea. The recovered oil drain tank will collect a mix of oil and water. The water will be drawn off the bottom of the tank and pumped through the oil-water separator. Water collected in the contact water collection sump can typically be pumped to the oil-water separator through a common line shared with the recovered oil drain tank. If there is a significant amount of hydrocarbons in the contact water it can also be pumped directly to the recovered oil tank to undergo initial separation of the hydrocarbons and water.

Floating hydrocarbon-on-water detectors will be used to detect any hydrocarbon sheens that develop on the surface of the remote impoundment reservoir, firewater reservoir and contact water collection sump. If hydrocarbons are detected, they will be removed using an oil skimmer, hydrocarbon absorption pads or a hydro-vac truck, or a combination thereof. Absorption pads will be disposed of in accordance with current regulations. Any hydrocarbon/water mixture extracted by hydrovac will be transferred to the recovered oil drain tank and processed with the contents of the tank.

A runoff study for the Kitimat Terminal will be done during detailed engineering to confirm the capacities of the site water management facilities.

It is anticipated that most water collected on-site will be rainwater and runoff water and will not be contaminated with hydrocarbons. However, facilities will be provided to manage the discharge of water to the ocean and so that any water released to the environment meets all environmental guidelines and standards.

Water in the Impoundment Reservoir

The remote impoundment reservoir will collect storm water from the tank terminal and other selected locations. Under normal operating conditions, water in the impoundment reservoir will be an accumulation of storm and surface water from site and will have no hydrocarbon content. This collected water will normally be pumped directly to the sea without additional processing. Two in-line analyzers will test water being discharged to the sea to confirm a hydrocarbon content of no greater than 15 ppm. The second analyzer will be interlocked to an emergency shutdown valve that will prevent discharge to the sea if the water does not meet the 15 ppm standard.

Oil-Water Separator

An oil-water separator will treat contaminated water to a 15 ppm oil-in-water concentration. The oil-water separator will conform to all appropriate design codes, including ULC-S656-2000 and CCME PN 1326.

The site water management system will allow any water collected onsite to be transported and processed through the oil-water separator. The discharge from the oil-water separator will be monitored prior to discharging to the ocean. If the water does not meet the 15 ppm standard, it will be redirected and processed through the oil-water separator again.

Recovered Oil Tank

A recovered oil tank at the foreshore will collect a mixture of oil and water from various sources. Typically, wash slops from the tankers will be transported directly to the recovered oil tank. If water from other locations on site—including the reservoirs, bermed tank areas, or the berth contact water sumps—becomes contaminated with oil, they would also be collected in the recovered oil tank to allow initial separation of the oil-water mixture. Water would then be drawn off the bottom of the tank and processed through the oil water separator, if needed.

9.5.5 Vapour Recovery Unit

A vapour recovery unit will be used to capture hydrocarbon vapours from tanker cargo holds during oil loading operations, condense it, recombine it with the oil and pump it back into the oil tanks. For the VRU process flow diagrams, see Appendix I, Figure I-17 and Figure I-18.

9.5.6 Potable Water System

Potable water will be trucked into the site. Piping and pumps will distribute water to the marine and tank terminal facilities, where needed. Potable water can also be loaded from shore to a moored ship, using a dedicated line on the gangway.

Any potable wastewater and sewage will be trucked off site to another location for disposal.

9.5.7 Utility Air System

A utility air system complete with compressor, separator and dryer will be installed in the terminal. A distribution system will provide compressed air to all buildings and areas of the terminal that need it. Compressed air will also be supplied to the tanker berths through distribution piping on the gangway.

9.5.8 Corrosion Control System

Steel structures that are not directly exposed to seawater will be protected from corrosion by paint. Steel structures exposed to seawater will receive additional corrosion protection including the use of epoxy coatings and cathodic protection.

External bottoms of field-erected tanks will be uncoated, but will be protected against soil-side corrosion by applying current from mixed metal oxide ribbon anodes installed within the tank base foundation.

Tanks will have an internal protective coating applied to the floor and the lower 1.2 m of the walls. The full height of the exterior walls, top of floating roof, the floating roof vapour space and the upper 0.6 m of the internal walls will also be painted.

9.5.9 Emergency Shutdown Systems

The tank and marine terminal facilities will incorporate several control systems including systems that will shutdown all or part of the facilities. Selected personnel will have access to manual shutdown systems. There will also be critical systems that will be interlocked to monitoring equipment and will shutdown automatically. The Shutdown Key will be developed during detailed engineering. Selected shutdown systems are described below.

Site Water Management System

Prior to discharging to the ocean, all collected site water will be tested by online analyzers. If the water does not meet the hydrocarbon standard of less than 15 ppm, an emergency shutdown valve will close to prevent discharge of water to the ocean.

Fire and Gas Detection

Fire, gas and other detectors will be provided at various locations. Activation of these detectors will involve alarming and shutdown of the energized equipment at risk from damage.

Loading Arms

The loading arms at the marine berths will be equipped with a powered emergency release system. In the event of severe stress being registered on a loading arm, two fast-acting, hydraulically actuated ball valves close and the arm is decoupled from the ship manifold. Spill volume is limited to the area between the two ball valves. This will be less than a 100-L spill if all four loading arms become decoupled. The spill volume would be contained and collected on the ship.

Delivery Lines Between the Tank Terminal and the Marine Berths

The delivery lines will be equipped with emergency shutdown valves that will facilitate the rapid isolation of the delivery lines. In the unlikely event of a pipe failure, the valves would be activated to limit oil or condensate discharge to environmentally sensitive areas such as the sea. The pipe would then be drained to the recovery tank. Additional actions and clean-up procedures will be described in greater detail in the emergency measures plan.

9.6 Tanker and Utility Berths

The Project includes two tanker berths that will provide simultaneous oil loading at both berths and single condensate unloading from either berth. The Project also includes a utility berth that may be used to support construction activities and service tugs during operations. For the locations of the berths, see Appendix I, Figure I-1.

9.6.1 Tanker Berths

The tanker berths will be designed to handle a range of tanker sizes (see Table 9-10). The characteristics are given for the largest sized VLCC, an average-sized Suezmax tanker and the smallest sized Aframax.

The tanker berths will each have the following major components:

- loading platform with gangway tower
- access trestles and catwalks
- berthing and mooring structures

Table 9-10 Design Vessel Specifications

Tanker Characteristic	Oil	Oil and Condensate	
Tanker class	VLCC (largest sized)	Suezmax (average values)	Aframax (smallest sized)
Deadweight (tonnes)	320,472 (summer load) 312,500 (winter load)	160,000 (summer load) 155,000 (winter load)	81,408 (summer load) 79,000 (winter load)
Overall length (m)	343.7	274.0	220.8
Beam (m)	70.0	48.0	32.2
Moulded depth (keel to main deck) (m)	30.5	23.1	18.6

Table 9-10 Design Vessel Specifications (cont'd)

Tanker Characteristic	Oil	Oil and Condensate	
Loaded draft (m)	23.1 (summer load) 22.5 (winter load)	17.0 (summer load) 16.6 (winter load)	11.6 (summer load) 11.3 (winter load)
Hull type[a]	Double	Double	Double
Average cargo capacity (m^3)	330,000	160,000	110,000
Estimated average cargo transfer rate (m^3/h)	12,800	8,000	6,400

NOTE:
[a] Only double-hulled tankers will be allowed at the Kitimat Terminal.

Several design options exist for the structure type and methods used to construct each major component of the tanker berths. For each major component, two structural options indicative of the range of viable alternatives were evaluated and a preferred option was selected (see Sections 9.6.1.1 and Section 9.6.3).

9.6.1.1 Loading Platforms

The loading platform at each tanker berth provides the interface for moving hydrocarbons between the tanker and the on-shore facilities. The loading platforms are designed as independent structures that support the loading arms, and may have a deck area of approximately 35 m wide by 58 m long. In addition to the loading arms, piping and other equipment will take up approximately 50% of the deck space. The remaining area will be available for mobile equipment such as a crane or truck. Vehicle access will be possible through one or more main trestles connecting the loading platform and the shore.

For the loading platforms, the two structural options evaluated were a jacket structure option and a pile and deck structure option.

For the jacket structure option, the concrete deck slabs of the loading platform are supported on modular steel framing and dual jacket structures. Each jacket structure consists of a four-legged, fully braced, tower-like steel assembly that is approximately 40 m high. The towers will sit on a level bench on the seabed excavated into the sloping bedrock and will be anchored to the rock to resist lateral forces.

For the pile and deck structure option, a composite concrete slab and box-girder deck is supported on individual steel pipe piles and pile caps. The individual piles will all be vertical and may be either partially or entirely filled with concrete.

The pile and deck structure option was selected as the preferred option because it needs less rock blasting and associated disturbance of the marine habitat compared to the jacket structure option. It also limits potential construction and operation issues associated with the quality of the rock.

9.6.2 Access Structures

Pile-supported access trestles will provide access from the shore to the loading platforms. The access trestles will be designed to accommodate a single lane roadway and the piping and utilities that extend from the shore onto the loading platform.

Conventional pile and deck construction similar to the loading platform will be used for the access trestles.

9.6.3 Berthing and Mooring Structures

The berthing structures will be independent structures located on either side of the loading platform and will be fitted with rubber fenders designed to absorb the lateral forces from a berthing tanker (see Appendix I, Figure I-1). Four fender locations, two on each side of each loading platform, will accommodate the range of design vessels.

For the berthing structures, the two structural options evaluated were a full jacket structure option and a buttressed (stiff-leg) structure option.

The full jacket structure option is similar to the jacket structure option evaluated for the loading platforms and uses the same member sizes and dimensions. The base of the each jacket structure will be set on flat rock benches on the seabed excavated into the sloping bedrock and then anchored to the rock.

For the buttressed or "stiff-leg" structure option, instead of individual berthing structures as proposed in the full jacket structure option, each set of side-by-side berthing structures is combined into one structure that is laterally supported by two stiff-leg space frames mounted to onshore concrete abutments.

The buttressed (stiff-leg) structure option was selected as the preferred option because it needs significantly less rock blasting and associated disturbance of the marine habitat compared to the full jacket structure option.

The decks of the berthing structures will consist of steel grating on a steel frame that is supported on the superstructure of the jackets or vertical piles. Mooring hardware will be anchored to a concrete slab cast into the deck frame of each structure. Alternative forms of construction could include either pre-cast or cast-in-place concrete caps, set on piles with mooring hardware anchored to the top surface.

A minimum of six mooring structures for each tanker berth will accommodate the range of design vessels. The mooring structures will be fixed structures located inshore from the fender line by a distance of 40 m or greater (where practical) and will be used to secure the mooring lines from the bow and stern of the tanker. They will be equipped with multi-line quick release mooring hooks.

Due to the proximity of the shoreline to the tanker berths, mooring structures may be located in the water, on-shore or a combination of both. An on-shore mooring structure option was selected as the preferred option because it needs significantly less rock blasting and associated disturbance of the marine habitat compared to the other options. On-shore moorings result in:

- mooring structures being located above highest high water level (HHWL) with no disturbance of the foreshore marine environment
- less drilling and blasting in the foreshore marine environment
- less shading by structure

The mooring structures will use rock-anchored concrete abutments and the mooring hardware will be cast directly into the mass concrete of the mooring structures.

A series of catwalks will be in place to provide workers with access between the loading platforms and the berthing and mooring structures.

9.6.4 Containment Boom

Each tanker berth will be equipped with an oil spill containment boom. The containment boom will be deployed during all oil loading operations. The containment boom will extend from shore, out around the tanker and back to shore. Because condensate dissipates quickly, the containment boom will not be used during condensate off-loading.

9.6.5 Utility Berth

Two options were considered for the berth construction: a concrete caisson and a floating structure. The concrete caisson was rejected on the basis that it entailed much more rock blasting and disturbance of the marine environment. The utility berth will have facilities that can accommodate the mooring of harbour tugs and two utility work boats. The utility work boats will be needed primarily for maintenance of the tanker berths and deploying the containment boom. A davit system will be used to launch the utility boats from the utility berth deck and retrieve the boats for stowage and maintenance.

10 Construction

10.1 Construction Schedule

Construction of the Project is scheduled for a 42-month period to achieve the planned in-service date. An additional 6-month period may be needed to complete construction of the Kitimat Terminal. Preliminary plans provide for the pipelines to be constructed using 12 spreads, ranging in length from approximately 74 to 192 km. Three spreads will be constructed concurrently during each of four construction seasons – the summer and winter of the first pipeline construction year and the summer and winter of the second pipeline construction year. Clearing activities for the first construction season will begin the year prior to pipeline construction. A comprehensive resource loaded and schedule constrained construction plan will be developed during detailed engineering and construction planning, taking into account factors such as:

- work force transportation and accommodations
- limitations on RoW access and the minimizing of multiple seasons of such access
- pipe transportation and stockpiling logistics
- coordination with other development activities
- restricted activity periods/windows
- regulatory, municipal, environmental and other commitments and issues to be managed
- available pipeline industry construction capacity

This execution planning will likely result in changes to the current plans described above, including the shifting of the construction season at some locations.

Procurement of long lead-time materials and equipment will be scheduled in advance of construction activities.

10.1.1 Contracting Strategy

A number of separate contracts will be awarded for construction of the pipelines. Separate contracts will also be awarded for construction of the tunnels, pump stations, Kitimat Terminal and tanker and utility berths. Additional contracts will be awarded for many associated construction activities and may include clearing, access road construction, pipe stockpiling, HDD crossing construction, pipeline aerial crossing construction, valve assembly fabrication, powerline construction and camp operation.

Northern Gateway plans to develop training and employment opportunities for participating Aboriginal groups and local communities as further described in Volumes 4 and 5A. Northern Gateway is also exploring potential arrangements with participating Aboriginal groups to provide procurement and supplier contracts.

10.1.2 Construction Resources

Labour and service needs and their associated influence on communities and infrastructure will occur during construction of the pipelines, pump stations and the Kitimat Terminal. For estimated labour requirements during operations and maintenance, see Section 11.6. Pipeline activities will proceed rapidly during the construction period, with peak employment for personnel and services occurring during the summer and winter months.

For a summary of the estimated numbers of personnel to construct the major project segments, see Table 10-1.

The construction personnel will have various skills ranging from entry-level labourers to highly skilled trades (see Table 10-2).

Table 10-1 Estimated Numbers of Construction Personnel

Project Segment	Approximate Personnel
Pipelines	600-800 for each of three spreads
Tunnels	100-150 for each of three locations
Pump stations	40-50 for each pump station
Kitimat Terminal	500-600

Table 10-2 Construction Skills

Construction Skills	Pipelines	Tunnels	Pump Stations	Tank Terminal	Marine Terminal
Boilermakers			X	X	
Carpenters		X	X	X	X
Electricians		X	X	X	X
Ironworkers			X	X	X
Labourers	X	X	X	X	X
Millwrights			X	X	X
Operating engineers	X	X	X	X	X
Pipefitters	X		X	X	X
Welders	X		X	X	X
Mariners/deckhands					X
Others	X	X	X	X	X

10.1.3 Construction Logistics

Logistics for the Project will involve moving equipment, materials and supplies to locations along the RoW, each pump station location and the Kitimat Terminal. Equipment, materials, camp facilities, water, food, fuel and other project supplies will be transported from major distribution centres by rail and truck using existing infrastructure and may also be transported by ship or barge, where practical.

Pipe will be transported primarily by rail to sidings that are located as close as possible to the RoW. Pipe will then be transported to stockpile sites and to the RoW by truck.

10.1.4 Construction Infrastructure

Construction camps will accommodate workers for most of the pipeline construction spreads, pump stations and the Kitimat Terminal, although local accommodation will also be used whenever possible.

Approximately eight construction camps of 25 ha each, accommodating approximately 500 to 800 personnel will be needed for pipeline construction. (Note that the environmental assessment in Volume 6A and Volume 6C assumes 11 construction camps for pipeline installation, based on an earlier project design.) The camps will accommodate living quarters, dining facilities, recreation areas, and equipment and maintenance areas. Pre-cleared areas will be used for the camps where practical. Where commercial power is not readily available, diesel generators will provide the power for the camps. Water will be withdrawn as permitted from nearby sources or hauled by truck and treated on site. Liquid and solid waste treatment will be handled in accordance with local regulations on site or hauled to an acceptable treatment facility.

A construction camp of 3 to 5 ha accommodating approximately 200 to 300 personnel will be in place for Kitimat Terminal construction. The camp will be either at an existing camp facility in the Kitimat town area or at the Kitimat Terminal.

Access to the pipeline RoW and facility sites will make maximum use of existing roads, and in particular forestry roads. Some road upgrading and new access road construction will be needed in remote areas and to access extreme slopes to assure safety for pipeline construction and work crew transportation. Access across watercourses will mainly be by temporary crossing structures, which will be constructed to meet applicable regulations and guidelines. Use of existing bridges across watercourses will be permitted as necessary or temporary bridges will be installed.

The utility berth (see Section 9.6.5) will be built during the early part of the Kitimat Terminal site development and may be used temporarily during construction as a construction berth.

Preliminary pipe stockpile locations and construction staging areas have been selected to provide the best logistical support for construction. The stockpile locations are in proximity to the railway sidings and the pipeline RoW and staging areas are in close proximity to the pipeline RoW.

10.2 Pipeline Construction

10.2.1 Construction Spreads

Construction of the pipeline component of the Project will be separated into manageable segments for seasonal construction periods to reduce the peak labour and equipment demands during construction. As mentioned previously (see Section 10.1), construction plans may be revised during detailed engineering and construction planning.

For the locations of the 12 pipeline construction spreads, and the associated construction seasons, see Table 10-3.

Table 10-3 Pipeline Construction Spreads

Construction Spread No.	Proposed Length (km)	Kilometre Post	Construction Season
1	192.0	0-192.0	Summer 1
2	87.9	192.0-279.9	Winter 2
3	93.0	279.9-372.9	Winter 1
4	103.4	372.9-4763	Winter 1
5	81.5	476.3-557.8	Winter 2
6	74.1	557.8-631.9	Summer 2
7	94.2	631.9-726.1	Summer 2
8	88.5	726.1-814.6	Winter 2
9	99.6	814.6-914.2	Winter 1
10	79.8	914.2-994.0	Summer 1
11	78.9	994.0-1072.9	Summer 1
12	99.3	1072.9-1172.2	Summer 2

Spread 1 is between the Bruderheim Station and Whitecourt, Alberta, and consists of generally rolling, privately owned agricultural land merging with Crown forest land in the western portion.

Spreads 2 to 5 are between Whitecourt and the Rocky Mountains to the east of the Continental Divide. This section is primarily forested Crown land having rolling topography with numerous watercourses and wetlands.

Spreads 6 and 7 run through the Continental Divide and consist of forested, mountainous Crown land with an area of wet terrain of variable topography, many watercourses, steep slopes and considerable surface rock exposure.

Spreads 8 to 10 are between Bear Lake and Houston, British Columbia, and consist of forested Crown land and limited private land over rolling topography with local wetlands.

Spreads 11 and 12 are through the Coast Mountain Range and consist primarily of forested and complex mountainous topography on Crown land with steep slopes, many watercourses and considerable exposure of surface and subsurface rock.

For typical drawings of various RoW configurations for the planned construction, see Appendix J, Figures J-1 to J-20. Additional RoW configurations to address site specific requirements will be developed during detailed engineering.

10.2.2 Construction Inspection

Qualified personnel will inspect the pipeline, pump station and Kitimat Terminal construction activities based on a documented inspection program to confirm that contractor operations comply with all applicable specifications and regulations.

An inspection team will monitor contractor activities for conformance with the construction, safety and environmental contract specifications. Quality audits will be undertaken for work in accordance with the project specifications. Further information will be included in the Construction Safety Manual.

10.2.3 Right-of-Way Preparation

A 50-m construction RoW, consisting of a 25-m wide permanent RoW and a 25-m wide temporary workspace will be cleared of vegetation, where needed. Extra temporary workspace, totalling approximately 10% of the construction RoW, will be needed at specific locations for highway, road, watercourse and utility crossings, grading along sloping terrain, timber salvage and other special circumstances. The additional temporary workspace will be finalized during detailed engineering. The clearing contractors will salvage timber and transport logs to a storage site or mill, clear remaining brush, grub work areas and dispose of slash in accordance with regulations and project specifications.

10.2.4 Grading and Soil Handling

The grade and ditch rock along the route will be ripped mechanically using bulldozers, where practical. Otherwise, controlled blasting techniques will be used for grade and ditch rock excavation.

The objective is to minimize grading of the RoW. However, grading must be sufficient to accommodate field bending and safe movement of pipe, equipment and personnel along the RoW. Grading along the RoW will vary from topsoil stripping in some areas to extensive cuts and fills in other areas. All RoW development will be in accordance with the Construction EPMP (see Volume 7A).

Where topsoil or organic materials are removed from the work area, they will be stockpiled separately at the edge of the RoW. Once construction is completed, the topsoil or organic material will be returned.

10.2.5 Pipeline Installation

Dedicated crews will complete the stringing, bending, welding, trenching, lowering-in and backfilling activities. Specialized crews will also be employed for road crossings, watercourse crossings and construction in difficult terrain.

The oil and condensate pipelines will generally be installed in separate trenches with a separation of approximately 8 m. However, the two pipelines may be installed in a common trench in certain situations, including, extreme slope areas, at major water crossings that are open cut, and large wetland areas.

Pipe will be trucked from local stockpile sites and strung along the RoW.

Field bending will be performed according to specifications. Induction bends will be installed where field bending radius cannot accommodate required bends.

Welding will be completed using a combination of manual shielded metal arc welding (SMAW) and mechanized gas metal arc welding (GMAW).

Hydraulic excavators or trenching machines will be used to excavate the trench depending on terrain and ground conditions. The trench bottom will be inspected and any protruding rock or debris will be removed to prevent damage to the pipe and coatings before lowering the pipe into the trench. In areas of blasting or abrasive trench materials, the bottom of the trench will be bedded with select or processed fine-grained backfill material, or the pipe will be coated with a suitable protective coating.

After installation, the pipe will be covered entirely with suitably selected backfill material from the trench excavation.

10.2.6 Fabricated Assemblies

Valve assemblies will be constructed through a combination of shop fabrication and field installation, which will be completed by pipeline crews.

10.2.7 Watercourse Crossings

Both pipelines will be installed concurrently at watercourse crossings where practical. Refer to Section 6, Watercourse Crossings, for a description of the various crossing techniques and the proposed crossing methodology for the watercourses.

10.2.8 Pipeline Cleaning and Pressure Testing

After each section of the pipelines is completed, internal cleaning scrapers will remove any construction debris. Debris will be collected and disposed of according to applicable regulations.

Each section of the pipelines will be pressure tested in accordance with CSA Z662-07. In most cases, water will be used for pressure testing. However, compressed air may be used in isolated steep mountainous terrain or in areas with limited water supply. Water for hydrostatic testing will be drawn from approved water sources and, after use, will be disposed of in accordance with regulations.

10.2.9 Cleanup and Reclamation

Prior to pressure testing, general cleanup will be completed along the pipeline RoW. Cleanup will include:

- removing construction equipment, materials and waste
- installing gates and fences
- re-contouring work areas
- compacting the trench, if needed
- replacing topsoil
- installing temporary or permanent erosion control measures, as needed
- reclaiming temporary construction access

No activity will be allowed over or adjacent to a pipeline that is under pressure test.

Work not completed during cleanup will be performed during final cleanup at the earliest available opportunity.

Reclamation of the RoW will involve regrading, as needed (e.g., areas having erosion gullies, vehicle ruts or trench settlement). The RoW will be recontoured as close to the preconstruction profile as practical, or to a stable angle of repose. RoW drainage patterns will also be returned to as close to preconstruction contours as practical and final erosion control structures will be installed. Topsoil will be prepared for revegetation and, ultimately, the RoW will be reclaimed according to landowner agreements and regulations.

Watercourse crossings will be reclaimed in accordance with project specifications. The RoW will be revegetated as necessary and as soon as practical on completion of final cleanup.

Equipment will be cleaned before it is demobilized from the construction sites.

10.2.10 Commissioning

Following completion of hydrotesting, the pipelines will be dewatered and prepared for commissioning and start-up. Prior to the introduction of hydrocarbons and start-up, leave-to-open approval will be obtained from the NEB.

The cathodic protection system will be connected to protect the pipelines from potential corrosion.

A nitrogen buffer will be maintained in front of the oil or condensate as line filling proceeds. Line filling will proceed from the respective initiating pump stations to the receiving stations.

10.3 Tunnel Construction

Two tunnels, approximately 6.5 km and 6.6 km long, will be constructed between the Clore River and Hoult Creek valleys.

10.4 Pump Station Construction

10.4.1 Site Grading

Site preparation at the pump station sites will involve clearing and grading approximately 4 ha at each site except at the Bruderheim Station, which will be approximately 2 ha. At sites where hard rock is present, it may be necessary to blast the rock to facilitate excavation.

Gravel access roads will be constructed from the nearest public road to each pump station.

10.4.2 Facilities Installation

Construction of the foundations for the pump stations will begin following rough grading and will be completed during the first year of construction. Work may be suspended during the winter months of the first year and recommence in the spring with the start of mechanical construction.

Construction of the pump stations and installation of valves will be completed several months before the in-service date to allow for the commissioning of the pipelines and facilities.

10.4.3 Testing and Commissioning

Prior to the introduction of hydrocarbons and start-up, leave-to-open approval will be obtained from the NEB. The pump stations will be commissioned and placed in service, in sequence with pipeline commissioning.

The various systems, including pumps, piping, control systems and other infrastructure, will be tested in accordance with current regulations and industry standards.

10.5 Kitimat Terminal Construction

10.5.1 Construction Sequencing

The following outlines a preliminary draft of the expected sequence for the construction of the Kitimat Terminal.

Tank Terminal

Tank terminal construction is expected to include the following steps:

1. Survey and stake the area.
2. Log entire site, including new roadway, material disposal site, and foreshore area.
3. Grub, chip, grind, and stockpile topsoil.
4. Improve the Bish Forestry access road, as needed, from the Rio Tinto site through to the northern end of tank terminal to allow access for initial construction equipment vehicles.
5. Install the security fence with temporary accesses, as needed.
6. Remove overburden and clay starting with material disposal site, new access road and tank lot.
7. Commence rock excavation at northern end of tank terminal. Initial excavated rock material will be used to construct the material disposal area retaining structure and the embankments and access road to the disposal area.
8. Construct retaining structure and continue with overburden and clay removal and storage as well as rock excavation. Only excess material will be placed in the excess cut disposal area, located outside of the security fence and north of the tank terminal area. Excavated material may be used for site development such as roadway, concrete aggregate, backfill and other on-site needs. After the retaining structure is completed and rough grade established, backfilled areas can be reclaimed with topsoil and other previously temporarily stockpiled vegetative materials.

9. Construct a new road along pipeline right-of-way between the Rio Tinto interchange and the main site. This road will become the main access road for the site. This construction will start at the tank terminal site and work back towards Rio Tinto to allow the use of excavated material from the tank terminal as the roadway construction materials. Part of this construction will include culverts for water management, bridge plate or arch culverts and ditches.
10. Prepare construction trailer and substation area after base course of retaining structure has been complete. At the same time, preparation of the construction laydown and batching plant area will begin.
11. Extend main access road to the south for haul road access. After the road has been extended beyond the southern end of the tank terminal, excavation of the tank terminal can start
12. Excavate the remote impoundment reservoir as well as the rough grading for the perimeter road.
13. Excavate the maintenance area after completion of the impoundment reservoir rough grade.
14. Start work on the impoundment reservoir infrastructure, including the liner, the berm walls, wet well, etc. If possible, collected rainwater will be used for construction purposes, such as concrete mixes and dust control.
15. Complete sit drainage system as areas are developed. Where the final site drainage cannot be completed, temporary drainage systems will be used. Details of the temporary and permanent systems will be developed during engineering design.
16. Reclaim exposed rock faces. This will improve the site appearance, help with the disposal of excess material and facilitate re-growth.
17. Start tank pad liner and tank pad construction, including leak detection, after rough grade has been established on the tank lot if the lot is not needed for other construction activities such as rock crushing, stockpiling, and construction laydown.
18. Start construction of the interior access road after the rough grade is complete.
19. Start tank construction when the tank pad is ready.
20. Install the following infrastructure in parallel with the tank construction and completion of security fence around the tank terminal:
    - undergrounds including duct banks and drainage systems
    - foundations for major equipment, pipe rack, and buildings
    - buildings and pipe rack
    - major equipment including pumps and substation
    - piping, electrical wiring and instrumentation
21. Install perimeter berms after the tanks are complete (including hydro-testing).
22. Source hydro-testing water from the impoundment reservoir. Depending on volumes, sequential filling of a tank may occur. Once a tank has been hydro-tested, the water will be transferred to the next tank for hydro-testing.

23. Install piping, including foundations.
24. Extend tank liner from the tank base to the perimeter berms and complete final grading after completion of the berms and piping installation.
25. Complete testing and commissioning.

Marine Terminal

Marine terminal construction is expected to include the following steps:

1. Survey and stake.
2. Grub and stockpile topsoil for entire foreshore area (includes chipping and grinding of vegetative matter).
3. Build foreshore access road (includes blasting and storage of excess material in the excess cut disposal area outside the security fence and north of the terminal area). The laydown areas for the initial part of foreshore development will be included in the tank terminal.
4. Start developing the utility berth, including for example:
   - dredging and blasting for utility berth anchorage area
   - drill and install piles
   - install approach ramp abutment
   - install floating utility berth
   - install approach ramp
   - install miscellaneous berth items including handrails
5. Continue development of the foreshore access road to the near end of the foreshore area where the main foreshore bench area starts at the same time as the utility berth is being developed.
6. Develop full width foreshore bench at a rough grade. It is anticipated that a mechanically-stabilized earth wall will be constructed along the length of the foreshore. Excavated materials from the rock cut will be used as backfill, such as behind the wall and road toppings. This material will also be used in the development of foundations (i.e. as aggregate or backfill) and general site grading.
7. Decide on handling of excess rock material, either:
   - place it in the excess cut disposal area
   - process and sell the excess rock to other markets. This would reduce the amount of on-site disposal.
8. Start excavating interface corridor between the tank terminal and the foreshore after the foreshore rough grade is complete.
9. Develop main berths. Material and execution for these structures will primarily be by way of floating barges, including power generation. The berth installation includes:
   - dredging and blasting for main berth anchorage

- drill and install piles (including pile caps)
- install concrete decks and fenders and mooring hooks
- blast, drill, and place abutment foundations and then install abutments for trestles and mooring structures
- install trestles
- install access roadway and associated hardware, including guardrails, etc.
- install the mooring hooks
- install catwalks, gangway structures, fire protection system, lighting and miscellaneous hardware

10. Install the following in parallel with the main berth construction:
    - undergrounds including duct banks and drainage systems
    - foundations for major equipment, pipe rack, and buildings
    - buildings and pipe rack
    - major equipment including pumps, meter skids, vapour recovery units (VRU), tankage and loading arms
    - piping, electrical wiring and instrumentation
11. Complete testing and commissioning.

10.5.2 Site Grading

Development of the Kitimat Terminal site will be undertaken using a blast-and-haul technique. The site will be developed in a staged approach, starting with the areas closest to the excess cut disposal area. A large volume of waste soil and rock will be generated during rough grading at the Kitimat Terminal site. The excess soil and rock will be transported to an excess cut disposal area using truck and shovel methods.

Topsoil and other vegetative materials will be either distributed around the site for aesthetic purposes or stockpiled on site for future site reclamation.

As areas are developed, they will be used on a temporary basis to support construction activities, including local rock crushers, concrete batch plants, temporary stock-piling, equipment laydown and temporary water impoundment. Initially, all locations will be developed to a design rough grade. No permanent facilities or grading are planned until all major blasting has been completed.

The current design calls for all tanks to be founded on tank pads that sit directly on bedrock or on concrete-ring foundations. Other structures will be founded either on bedrock or placed on piled foundations as appropriate.

Final grades will be established as allowed by the construction sequence.

10.5.3 Facilities Construction

Construction of the foundations for the tanks, pipe racks and equipment will start as site grading is completed.

Terminal construction will include the oil and condensate tanks, piping delivery systems and topside facilities, including the tanker loading and unloading arms. Ancillary facilities such as the control building and security infrastructure will also be constructed on site. The initiating condensate pump station will be constructed as described in Section 10.4.

10.5.4 Tanker Berths

The tanker berths will consist of a series of independent structures, including loading platforms, and berthing, mooring and access structures. Marine construction will involve both underwater and above-water work, including drilling and grouting of piles, assembly and erection of steel and concrete structures, and installation of topside equipment and marine facility appurtenances. The marine construction method is highly dependent on the type of structure and design of the foundation.

To facilitate construction of the marine structure foundations, as well as provide adequate underkeel clearance for moored vessels, certain areas of the marine terminal site may involve dredging of overburden soil material in addition to blasting and removal of rock material. This material will be transported to an excess cut disposal area to the extent practical. However, some of the blasted rock will fall to the sea bottom.

Pile and deck structures and buttressed (stiff-leg) structures are proposed for loading platforms and berthing structures. On-shore structures are proposed for the mooring structures.

Marine structures supported on individual piles will typically have the piles installed using a conventional drill derrick and will be either doweled or socketed into the rock. To account for the larger placement tolerances of individual piles, cast-in-place pile caps will be installed around the individual pile heads. Deck structures consisting of pre-cast concrete beams or pre-assembled steel frames can then be efficiently erected with barge cranes onto the pile caps. Pre-cast concrete deck planks are then placed on beams or frames and finished with a cast-in-place concrete surface.

10.5.5 Testing and Commissioning

The various systems including tanks, piping, control systems and other infrastructure will be tested in accordance with current regulations and industry standards.

Pre-commissioning activities and testing will typically involve the use of non-flammable, non-toxic mediums such as water, air and inert gases whenever possible. If alternative liquids are used, appropriate contingency plans shall be developed to protect the environment in the event of leakage during testing.

Tanks will be hydrostatically tested with freshwater or stormwater collected in the remote impoundment reservoir. Hydrostatic test water will be transferred from tank to tank for each subsequent test. At the completion of all tests, the water will be managed according to applicable regulations.

Piping will be hydrostatically tested with water collected in the remote impoundment reservoir or trucked in from off site. All piping will be tested to a pressure that will allow it to be operated up to the pressure rating of the flanges. In situations where changes in elevation of the pipe will result in the test pressure at the lower elevations to be excessive, flanges will be installed in intermittent sections of the line to allow hydrostatic testing of the pipe in sections. A detailed hydrostatic testing plan will be developed prior to testing.

Loading arms will be fully tested by the supplier prior to installation. Additional field testing will be completed under the direction of the supplier and in accordance with all current regulations and industry standards.

The control system testing will involve calibration and testing of individual instruments followed by testing of the control system as a whole. This testing will include the emergency shutdown, control, and relief systems in a safe and controlled manner.

Following successful completion of pre-commissioning of the terminal facilities and tanks, and prior to introduction of hydrocarbons and start-up, leave-to-open approval will be obtained from the NEB.

After mechanical completion, commissioning of the tank terminal and marine terminal topside facilities will commence. Commissioning activities will introduce the oil and condensate that will be transported through the pipelines and terminal.

The commissioning team will prioritize the systems to be tested and commissioned along with the piping, equipment, power and controls.

11 System Operations

The pipelines and facilities associated with the Project will be operated in accordance with applicable regulatory approvals and Enbridge standards.

Enbridge operational policies, practices and activities prioritize safety and stewardship of the environment.

The pipelines and facilities will be monitored and operated from the Enbridge Edmonton Control Centre. The Kitimat facilities associated with vessel loading and unloading will be monitored and operated from the Kitimat Control Centre.

The Project will be designed with emergency shutdown systems that can be initiated remotely or locally if an unsafe condition is detected. Twenty-four hour, on-shift support for Material Balance System (MBS) alarms and troubleshooting will be provided at the Edmonton Control Centre. Data will be made available to technical support locations, maintenance bases and third-party locations, as defined by the project operational plans.

Project operations and maintenance manuals and emergency response plans will be in place before operation starts. Qualified employees will operate the pipelines and facilities in a safe and reliable manner.

11.1 SCADA System Description

A supervisory control and data acquisition (SCADA) system will be installed to enable the pipelines and facilities to be remotely controlled and monitored simultaneously from both control centres to be located in Edmonton and Kitimat.

The SCADA system will be configured so that the following facilities and operations will be controlled and monitored remotely from the Enbridge Edmonton Control Centre:

- pumps and other facilities delivering into the initiating oil pump station at the Bruderheim Station
- pumps and other facilities delivering into the initiating condensate pump station at the Kitimat Terminal
- oil and condensate pumps at each intermediate pump station
- monitoring of custody transfer metering
- material balance information to confirm the integrity of the pipeline system
- flow rates and operating pressures in the oil and condensate pipelines at the discharge and suction side of each pump station and at the Kitimat Terminal
- pipeline valves and remote monitoring of hydrocarbon temperatures and pressures at the pipeline valve sites

- tank levels, oil and condensate tank transfer pumps, pressure regulation
- monitoring of tanker loading and unloading operations performed by the Kitimat Control Centre

The SCADA system will also be configured so that the following facilities and operations will be controlled and monitored from the Kitimat Control Centre:

- tanker loading and unloading facilities
- custody transfer metering
- monitoring of Kitimat site facilities for which primary control resides with the Edmonton Control Centre

11.2 Control Centres

The safety and integrity of the system will be maintained through the coordination efforts of all support personnel. Personnel will be trained on a computerized simulator at the Edmonton Control Centre.

The Edmonton Control Centre will be used to monitor and control the pipelines, pump stations, valve sites and tank terminal facilities. The Edmonton Control Centre has a fully redundant backup control centre in the Edmonton area that is separate from the primary site. Operators can take full control of the pipeline systems from this location within one hour of the primary control centre becoming unavailable.

The Kitimat Control Centre will be used to monitor and control the tanker loading and unloading operations at the marine terminal, as well as the associated terminal equipment. A system redundancy backup plan for the Kitimat Control Centre, similar to that of the Edmonton Control Centre, will be further evaluated during detailed engineering.

Tanks at the Kitimat Terminal will be controlled by the Edmonton Control Centre for material balance management, with the Kitimat Control Centre always monitoring and able to control as emergency backup. The facilities associated with the loading and unloading of tankers will be controlled by the Kitimat Control Centre with the Edmonton Control Centre monitoring.

The proven equipment and software used at the Edmonton Control Centre will enable operators to remotely monitor and control all elements of the pipeline systems, including the tank terminal, pump stations and valves, line pressures, flow rates, custody transfer meters, gas and fire detectors, and numerous safety systems.

The SCADA system was developed and is currently supported by Enbridge staff. This SCADA system has evolved over almost 40 years and is very robust and complete. It has many proprietary features built in that allow Enbridge to safely maximize pipeline capacity while minimizing risk.

A dedicated team of engineers, operations coordinators and supervisors together with a modern in-house training centre currently support the Edmonton Control Centre and will support the Kitimat Control Centre.

Initial response to a Control Centre MBS alarm will be in accordance with current control centre operations (CCO) procedures and in compliance with all applicable codes in effect at the time of the design. Enbridge's current procedures require initiation of a line shutdown within 10 minutes of receiving an unexplained MBS alarm and initiation of the specific subsequent steps depending on the nature of the alarm.

11.3 SCADA System Operations

The SCADA system will be supported by Enbridge's software system, PROCYS, which has been developed by and maintained by Enbridge. PROCYS is a graphical user interface (GUI) software system that provides the means to remotely monitor and control critical aspects of the pipeline operations.

Data transmitted from the stations and terminal by the SCADA system includes pressures, set-points, pump and valve status, tank levels and various station alarms. This information is displayed for the pipeline controllers and monitored by PROCYS for alarms and other unusual conditions. Based on the displayed information and the pumping schedule for the day, the pipeline controller can control pipeline operations and pipeline-related terminal operations by adjusting pressure set-points, opening valves and initiating pump unit starts or shutdowns, station shutdown or complete line shutdown. For pipeline operation, the pipeline controller can set holding, suction and discharge pressure set-points to control the flow rates and line pressures and can also remotely open or close the block valves to safely shutdown the pipelines.

PROCYS also provides automatic backup pressure protection through a number of subroutines. For example, an extension to the line pressure monitor (LPM) alarm system monitors the discharge pressure at one station and the suction pressure at the downstream station. The LPM can initiate set-point reductions, unit shutdowns at the upstream station or entire line shutdowns. In addition to these primary functions of pipeline control, PROCYS also provides several analytical tools, including a selection of preconfigured or customized graphical trends and reports. These tools are used in the analysis of both normal pipeline operations and operational irregularities that may occur.

11.4 System Communications

A communication system will be in place, which includes redundant equipment and alternative data routes for the pipeline controller to maintain control over the terminal, pump stations and remote valve sites.

A combination of wide area network, telephone lines, satellite and radio communication circuits will provide main and backup communication systems to remote terminal units (RTUs) at the terminal, pump stations and valve locations. Satellite communication circuits will use "report by exception" communication, in which the RTUs report changes in the terminal or pump station data to the control centre as soon as changes are detected.

The Kitimat Terminal and pump stations will be connected to network services supplied by a qualified service provider. The communications system will be equipped with a wide area network and voice communication interfaces. The lines will provide infrastructure for dial-up voice communication and the SCADA data link to the Edmonton Control Centre.

The Kitimat Terminal and pump stations will be equipped with a satellite data link to provide backup SCADA communications. Alternative voice communications at the terminal for marine operations will be provided to comply with Canadian Marine Transport Security.

Pump stations will have a local Ethernet network to provide an interface between local computer systems and programmable logic controllers.

Network connections inside buildings will use conventional wiring. Links between buildings will use fibre optic cable.

11.5 Security System

Enbridge's security management system will be implemented for the Project and will include the following:

- security policies and procedures
- regional security response plans
- security vulnerability assessments
- threat monitoring and analysis
- physical security measures
- monitoring, tracking and trending of security incidents
- training and support

The types of physical security measures at facilities may include perimeter fencing, intrusion alarms, surveillance systems and lighting. Northern Gateway will work with local and federal policing authorities and industry associations to identify and monitor security trends and issues.

11.6 Operations and Maintenance

Regional maintenance centres will be established at Kitimat and at a number of locations along the pipeline route. It is expected that over 100 long-term personnel will be directly employed to operate and maintain the pipelines and related facilities. See Table 11-1 for a summary of the estimated number of operations personnel and their respective skills.

More than 100 additional long-term personnel are also expected to be employed for support services related to the Kitimat Terminal and shipping operations.

Operational activities along the RoW will include regular aerial and surface surveillance to identify any third-party encroachments, excavation or other construction activity, and natural events (rock or snow slides). In addition, to properly monitor the RoW from the air, maintenance work such as vegetation brushing and clearing will be carried out as needed. Other work performed on the RoW will consist primarily of preventative maintenance, testing and associated repair of pipeline valves, the cathodic protection system and other associated facilities including the Kitimat Terminal.

Table 11-1 Operations Personnel

Personnel Skills	Alberta	Kitimat	Other BC	Total
Electrical/Mechanical Technicians	5	5	5	15
Pipeline Maintenance Technicians	10	5	10	25
Technical Supervisors	2	3	2	7
Control Centre Operators	5	5	0	10
Environmental and Land Coordinators	2	5	4	11

Table 11-1 Operations Personnel (cont'd)

Personnel Skills	Alberta	Kitimat	Other BC	Total
Area Managers	2	0	4	6
Administration Assistants	1	1	1	3
Tank Operations Technicians	0	11	0	11
Marine Operations Technicians	0	4	0	4
Terminal Manager	0	1	0	1
Regional Office Staff	0	12	0	12
Total	**23**	**52**	**26**	**105**

Typical maintenance for the Project will include the following activities:

- cathodic protection and monitoring
- pipeline integrity, inspection and maintenance
- valve monitoring inspection and repair
- vegetation control
- investigation and control of encroachment from third parties
- monitoring watercourse crossings including depth of cover for the pipelines
- tank inspections
- maintenance of above grade facilities

The tanks will be inspected in accordance with API Tank Inspection Standard 653. The inspections will include the scheduled in-service inspections and out-of-service inspections to monitor the safety and integrity of the tanks.

11.6.1 Operations and Maintenance Manuals

Enbridge's existing pipeline operations and maintenance manuals will be used as the basis for operating the project pipelines and related facilities. These manuals will be revised to reflect the changing needs of the Project.

The operations and maintenance manuals currently include:

- general reference procedures, including topics such as regulatory compliance, incident reporting, public awareness, record keeping and training
- safety procedures, including topics such as safe work practices, hazard assessment, confined space entry, fire protection, lock-out and tag-out and personal protective equipment
- pipeline facility procedures, including work planning and preparation, environmental protection, RoW maintenance, foreign crossings, pipe repair and testing, and tank maintenance
- welding procedures, including welder qualifications

- petroleum quality and measurement procedures to confirm hydrocarbon quality and custody transfer measurement accuracy
- emergency response procedures, including pre-emergency preparedness, emergency response responsibilities and actions, hydrocarbon containment, recovery and cleanup, local release control point mapping and mitigation measures

11.6.2 Routine Maintenance

In-line inspection tools will assess the integrity of the pipelines on a scheduled basis in accordance with the established pipeline maintenance plan. Periodic excavations will be conducted at locations along the pipelines for tool calibration and verification, as well as for pipeline investigation and repair.

The Project’s operations and maintenance facility sites will be located along the pipelines and at the Kitimat Terminal. Qualified operations personnel will be deployed from these maintenance areas to service the pipelines and associated facilities. A comprehensive emergency response system, including appropriate equipment and trained personnel, will also be in place to address any situations that may arise.

An ongoing public awareness program will be implemented that will regularly communicate with participating Aboriginal groups and stakeholders including landowners, communities, government agencies, and emergency response officials such as police agencies and health care providers. Information regarding the pipeline operations and emergency response incidents and training exercises if any have occurred, will be provided regularly to the public. The pipeline RoW will be marked at regular intervals with emergency contact information. A 24-hour emergency call centre is operated at the Edmonton Control Centre to respond efficiently and effectively to any public concerns or emergency conditions. The comprehensive emergency response system will include many preventative actions such as advanced education of the public regarding pipeline crossings and encroachment issues.

The Project will also work with local emergency response workers to undertake training and education activities, including mock spill response exercises.

11.7 Batching

The oil pipeline will operate as a batch system where a variety of segregated hydrocarbons will be transported in the pipeline. Batching pigs will be used where necessary to limit batch interface mixing. Instrument-controlled autopig bypasses will be installed to limit contamination from the station piping and to avoid cycling the pipeline. Upstream batch detection facilities are required to generate a profile to allow batches to be properly cut at the Kitimat Terminal. These facilities will be located in a small heated building several kilometres upstream of the terminal.

11.8 Pump Stations

Pump stations will normally be unmanned, but will be provided with a network workstation, station controls and unit controls for when technicians are on site. The pump stations will be monitored as part of the overall pipeline SCADA system displays at the Edmonton Control Centre.

A computer-based control system will be provided at each pump station to monitor pump units and control station safety functions. The system will provide the ability to control the station operating pressures and valves.

The control system will provide the ability to start-up and shutdown pumps using logic that will prevent pressure surges in the pipelines from exceeding the specified maximum value.

The temperature, pressure and vibration of all major equipment at all pump stations and the Kitimat Terminal will be monitored. The operator at either the Edmonton or Kitimat Control Centres will not be able to restart defective equipment before repairs and reset of a local lockout mechanism.

11.9 Leak Detection

A real-time transient model (RTTM) MBS computer program will be used for pipeline leak detection. Hydrocarbon sensors and on-site personnel will be used for facilities leak detection.

The MBS will be designed in accordance with OPR-1999 and the CSA Z662-07 Annex E. The MBS applications will reside on a dedicated high-capacity UNIX server that is separate from the SCADA servers.

The MBS graphics and other MBS displays will be displayed on a separate computer monitor at the Edmonton Control Centre consoles. MBS alarms will be passed to the SCADA system and will appear on the SCADA monitors for response by control centre personnel.

Alarm thresholds will be established during the tuning period of the new system development. The alarm thresholds are different for each pipeline as each pipeline is unique in design and operation. Imbalance alarms from the MBS mainline leak detection system are annunciated in the Control Centre. The Control Centre response procedures for possible pipeline leak situations would be initiated.

11.10 Kitimat Terminal

Operations at the Kitimat Terminal will consist of custody transfer measurement of receipt and delivery volumes as well as tank gauging. Preventative maintenance will be performed along with regularly scheduled safety and integrity inspections.

Tanks will be inspected internally and externally as per the API guidelines so that they are in good working order.

Other equipment, such as pumps, loading arms, and valves will be inspected and maintained so that they are in good working order. The frequency of inspection and maintenance will be established in the site operating and maintenance procedures and will be dependent on current regulations and manufacturers specification. Routine upgrading of equipment will be conducted, as needed. An operations and maintenance manual will be in place for the Kitimat Terminal. Inspection and monitoring programs for the Kitimat Terminal are described in Section 12.2.

11.10.1 Tanker Berth Operations

11.10.1.1 General

All tankers arriving at the Kitimat Terminal will be assisted by harbour tugs during the berthing operation. Before a tanker arrives at the terminal, a meeting will be held between the shipmaster and officers and the coastal pilot to review berthing operations, harbour tug positions, terminal mooring plans, mooring line connection sequences, mooring operation safety and other related activities. To assist in the berthing operation, the terminal berths will be equipped with a docking aid system that will monitor and display the vessel's distance, speed and angle of approach.

Once a tanker has completed its arrival manoeuvres and has been assisted onto the berthing structures by the tugs, the tanker will be ready for its mooring lines to be secured by trained terminal personnel. After the mooring lines are secured, the hydraulic ship-to-shore gangway will be deployed to allow access to the vessel. A containment boom will be deployed during all oil loading operations (see Section 9.6.4).

11.10.1.2 Preloading Procedures

Arrival documents (as required by the ship's agent and terminal) will be completed before cargo transfer operations begin. Proper entry and clearance by Canada Customs will be obtained. A pre-transfer meeting will be held involving the terminal's operation personnel, the ship's master, the ship's chief engineer, and the senior ship's officer in charge of the cargo transfer and ballast operations. After operational and security procedures have been discussed, terminal personnel and a third party surveyor will inspect the tanker's cargo tanks, establish communication links between the tanker and terminal and complete a tanker safety inspection and safety checklist. Any inspection failures must be addressed before unloading begins.

The vessel's safety inspection will include ensuring the vessel's inert gas system is in good operational condition. The inert gas system is critical as it eliminates oxygen in the vessel's cargo tanks, thereby ensuring the safe operations of the vessel. Unloaded vessels arriving at the terminal will be inspected to confirm that their empty tanks contain inert gas at the prescribed concentration.

After the pre-transfer meeting, and in coordination with the vessel's cargo officer, loading arms will be manoeuvred into position and connected to the tanker's manifold by terminal personnel. Before arrival, the tanker crew will prepare the manifold connections to match loading arm size.

Vessels will follow procedures as recommended in the latest version of the International Safety Guide for Oil Tankers and Terminals and all other applicable rules and regulations.

11.10.1.3 Cargo Transfer Operations

Cargo transfer operations typically take 18 to 30 hours for oil cargo loading and 16 to 24 hours for condensate cargo discharging (unloading) depending on the vessel size and cargo transfer flow rate. Typically, transfer flow rates are ramped up gradually to confirm there are no leaks in the system.

Ballasting operations will be conducted concurrently with the cargo transfer operations. All vessels using the Kitimat Terminal will follow The Canadian Ballast Water Management Guidelines. Oil tankers will have segregated ballast on board that has been exchanged not less than 200 nautical miles from shore, as described by these guidelines.

For a loading operation, the vessel will discharge clean segregated ballast water into the sea as oil is loaded into the vessel's cargo tanks. Refer to Volume 8A, Section 4.7.11.5 Ballast, Slops and Bilge Water for a description of ballast water management. For a discharge (unloading) operation, water will be pumped into the segregated ballast tanks, as condensate is unloaded from the vessel's cargo tanks.

The berths will be equipped with a safety control system that will allow terminal personnel to continuously monitor oil and condensate transfer operations from the marine control building. The safety control system also allows the terminal personnel to continuously monitor tanker movements at the berth, weather information, mooring line forces and other important safety parameters.

Ship-to-shore communications will be maintained throughout the entire process using explosion-proof handheld radios, which are equipped with anti-spark devices. The ship's master will typically give terminal personnel 30-minute, 10-minute and 1-minute notices before completing loading and unloading. After loading and unloading operations are completed, the terminal personnel will drain and disconnect the arms.

11.10.1.4 Departure Operations

Final departure procedures and documentation to be completed by the ship's agent, vessel crew and terminal personnel will be in accordance with the Terminal Operations Manual. In coordination with the ship's crew, the shore-side mooring crew will release the mooring hooks as directed by the shipmaster and pilot. Tugs will be in attendance during the unmooring process; mooring lines will be reeled in using the vessel's deck winches, after which the vessel will be ready for departure with the assistance of the harbour tugs. Additional details of tanker operations are provided in Volume 8A.

12 System Integrity

Integrity management entails risk identification and assessment. Various tools will be used to generate, assess and evaluate operational risks applicable to the project pipelines and facilities. The integrity assessment results will be used to prioritize maintenance activities or projects so that fitness-for-purpose tolerances are maintained. These activities will be formalized in various integrity management programs, based on the type of issue being considered.

Each integrity management program will use documented policies, procedures and practices that so that events are accurately documented, roles and responsibilities are defined, consistency is maintained, decisions are easily communicated and justified, and continuous improvement occurs.

The integrity management programs will confirm the operational reliability of all system components including the pipelines, pump stations, tank terminal and marine terminal piping, and tanks. Integrity management programs will also ensure compliance with regulations.

12.1 Pipeline Integrity

The primary goal of the pipeline integrity program is to prevent leaks and ruptures caused by duty-related deterioration of the pipelines. The principal objectives of this program are to:

- safety of employees and the public
- protect the environment
- provide reliable pipelines
- maintain the system as a long-life asset
- strive to achieve zero leaks or ruptures

The pipelines will be monitored to identify defects that may occur and so that remedial action is taken in a planned approach so that the objectives of the integrity management program are realized. Northern Gateway's approach to pipeline integrity management will be based on applying risk-control measures over the lifecycle of the pipelines so that a constant base integrity level is maintained.

The following sections outline the integrity management activities that will be applied to the pipelines.

12.1.1 Prevention Programs

The risk of pipeline failure will be reduced through careful planning of the pipeline route, selecting suitable construction materials, limiting operating stress through the design factor, and ensuring a high-quality pipeline installation. The pipeline integrity activities associated with these efforts are as follows:

- pipeline design, construction and operation reviews:
  - integrity personnel will participate with project development teams to provide expertise regarding the integrity measures needed for a long-life asset, based on the proposed operating regime and consideration of the hydrocarbons being shipped, the terrain that will be traversed, hydraulics, pressure patterns and other properties that affect pipeline integrity

- development of construction practices and material specifications, including:
  - engaging metallurgical expertise to select line pipe steel and welding procedures
  - identifying and specifying protective paints, coatings and linings to protect pipe and facilities from corrosion
- incorporation of QA/QC measures, including:
  - developing and implementing non-destructive testing procedures and implementation specifications
  - ensuring contractors and company personnel, who are involved in implementation of integrity related activities, receive proper training

12.1.2 Monitoring Programs

Appropriate design, construction and operational measures, combined with ongoing monitoring programs, will be used to monitor corrosion, cracking and other defects that have the potential to cause deterioration of pipelines. The following are some of the techniques that will be used to monitor integrity of the pipelines and to assess operational data:

- cathodic protection, including:
  - an annual pipe to soil survey along the pipelines
  - monthly monitoring of rectifiers and ground bed systems
- in-line inspection to locate and measure the size of any defects. Defects will be analyzed and monitored through regular inspections. The inspection intervals will be established using the integration and analysis of numerous data sets.
- investigative excavations will be used to assess anomalies and obtain information related to soil types, water, topography, coating condition and other characteristics to develop a better understanding of the root cause of the pipeline anomaly. These investigations will be conducted if anomalies are identified by in-line inspection. The selection of a specific location for the excavation will be based on a combination of:
  - fitness for service analyses of specific defects
  - direct assessment approach or
  - in conjunction with a planned maintenance activity
- A slope stability monitoring program that includes monitoring sensitive slopes for ground movements and assessing the potential effects that these movements could have on the integrity of the pipelines. Monitoring may include instrumentation, regular visual inspection, pipe assessments, or some combination. Remediation or reconstruction projects or both would be implemented to confirm the ongoing integrity of the affected pipelines.

12.1.3 Mitigation Programs

To manage risks posed by pipeline deterioration, anomalies identified through monitoring will be categorized using comprehensive fitness-for-purpose criteria. Anomalies that do not meet acceptance criteria will be repaired.

Mitigation measures for the Project include sleeve repairs, pipe replacements, pressure reductions, rehabilitation and inhibitor injections, depending on the specific situation.

12.2 Facilities Integrity

The terminal will be a fully manned site and will undergo regular maintenance and monitoring of facilities that meets all company standards as well as all applicable codes.

Northern Gateway will implement facility-based integrity programs administered by the Project's program coordinators, engineers and regional operations personnel. The programs will be a combination of regulated activities and proactive measures to provide a continuous, safe, reliable and environmentally responsible operation. In addition to program development and implementation, regular reviews will be conducted on performance data to determine if focused, short duration initiatives are warranted.

There will be an inspection program for all components of the marine facilities, such as:

- berthing structures
- mooring hardware
- fender systems
- loading arms
- piping manifolds and supports
- fire detection and suppression systems
- communication equipment
- gangways
- lighting
- cathodic protection system
- safety ladders

Periodic inspections will be completed throughout the year. Extended inspections will be conducted whenever the periodic inspections indicate the need. Special inspections will be performed before and after maintenance and repair work.

As part of the operation of the marine terminal, the berthing structures will be subject to regular above and below water inspections to monitor for any degradation of the structural elements. Regular maintenance will be completed to reduce the possibility of accelerated deterioration that could occur as a result of exposure to the sea water environment.

Cathodic protection for the tanks will be monitored regularly for its functionality. A leak detection system will be included in the tank design to monitor for leaks below the tanks. The tanks will be subjected to regular inspection protocols at intervals specified by API. These inspections will include wall thickness, coating integrity, tank base settlement and welds.

All terminal piping will be above ground and its inspection will be included as part of regular maintenance practices. Pipe will be visually inspected to confirm there is no corrosion, leaks or other evidence that would indicate the pipe is not in good condition. Additional non-destructive or destructive tests would be done as appropriate to confirm integrity of the facility.

Mechanical equipment, such as pumps, loading arms, metering facilities, and valves will be inspected and maintained to confirm they are in good working order. The frequency of inspection and maintenance will be established in the site operating and maintenance procedures. Where needed, equipment will have alarms to indicate any operational parameters not within specifications. Redundant tank level detection will be installed.

Valves will be inspected and cycled in accordance with industry standards as part of regular maintenance practices.

Safety systems will be inspected and tested on a regular basis to confirm they are in good working order. The frequency of inspection and testing will be established in the site operating and maintenance procedures.

The following programs will be applied to the pump stations, valve sites and the Kitimat Terminal:

- leak history tracking and analysis
- flange integrity program
- above-ground tank inspection program
- facility piping integrity program
- small diameter piping program
- site water containment and drainage program
- pressure vessel inspection program that meets or exceeds ASME Boiler and Pressure Vessel Code (Section VIII) or its local equivalent.
- life cycle management program for the marine structures
- inspection program for the marine structures
- tank inspection program, including wall thickness and coating assessment
- valve inspection and cycling program
- above ground pipe inspection program

13 Decommissioning

If a pipeline or facility is to be decommissioned or abandoned, Northern Gateway will develop decommissioning and abandonment plans in consultation with relevant stakeholders, participating Aboriginal groups, the NEB and other authorities and agencies.

Regulations, environmental issues and safety issues associated with decommissioning and abandonment options will be considered when developing these plans. These options include:

- physical elements, such as the physical environment, soil capability, water quality and quantity, air quality and the acoustic environment
- biological elements, such as fish and fish habitat, wetlands, vegetation, wildlife and species-at-risk
- socio-economic elements, such as human occupancy, resource use, infrastructure and services, and accidents and malfunctions

The decommissioning and abandonment plan will comply with the current regulatory standards in effect at the time of decommissioning. Appropriate regulatory applications will be filed (for example, Section 74 of the *NEB Act*). Decommissioning or abandonment activities will be subject to examination pursuant to applicable regulations.

A preliminary list of activities for decommissioning the Kitimat Terminal is based on current legislation. Future changes to regulations may alter the activities. The activities are based on abandoning the site and reclaiming the land (i.e., removal of structures). Aboveground structures will be removed, but below ground structures may be abandoned in place.

13.1 Tank Terminal Activities

Tank terminal decommissioning is expected to include the following steps:

1. Empty, clean, demolish and remove all tanks, piping, meter skids, drain lines, transfer pumps, VRU, recovered oil drain tank, plus the loading arms on the marine berths. Buried piping will be abandoned in place.
2. Demolish and remove all piperacks, trestles, gangways, buildings, instrumentation and electrical infrastructure.
3. Cut off all foundations below grade.
4. Remove tank liner ensuring no residues enter the ground below and demolish the berm.
5. Drain contents of impoundment pond and remove liner. Wastewater will be treated, if needed, prior to disposal.
6. Perform soil and water testing to assess the environmental quality of the site. If testing finds the site to be contaminated clean-up and remediation shall be done, as appropriate.
7. Reclaim stockpiled topsoil and vegetative material and return the land to its natural vegetative state.

8. Apply slope stabilization and erosion control measures to the site, as needed.
9. Remove guard rails and signage on roadside. The road surface will be left as is.
10. Remove gates and fences.

13.2 Marine Terminal Activities

Marine terminal decommissioning is expected to include the following steps:

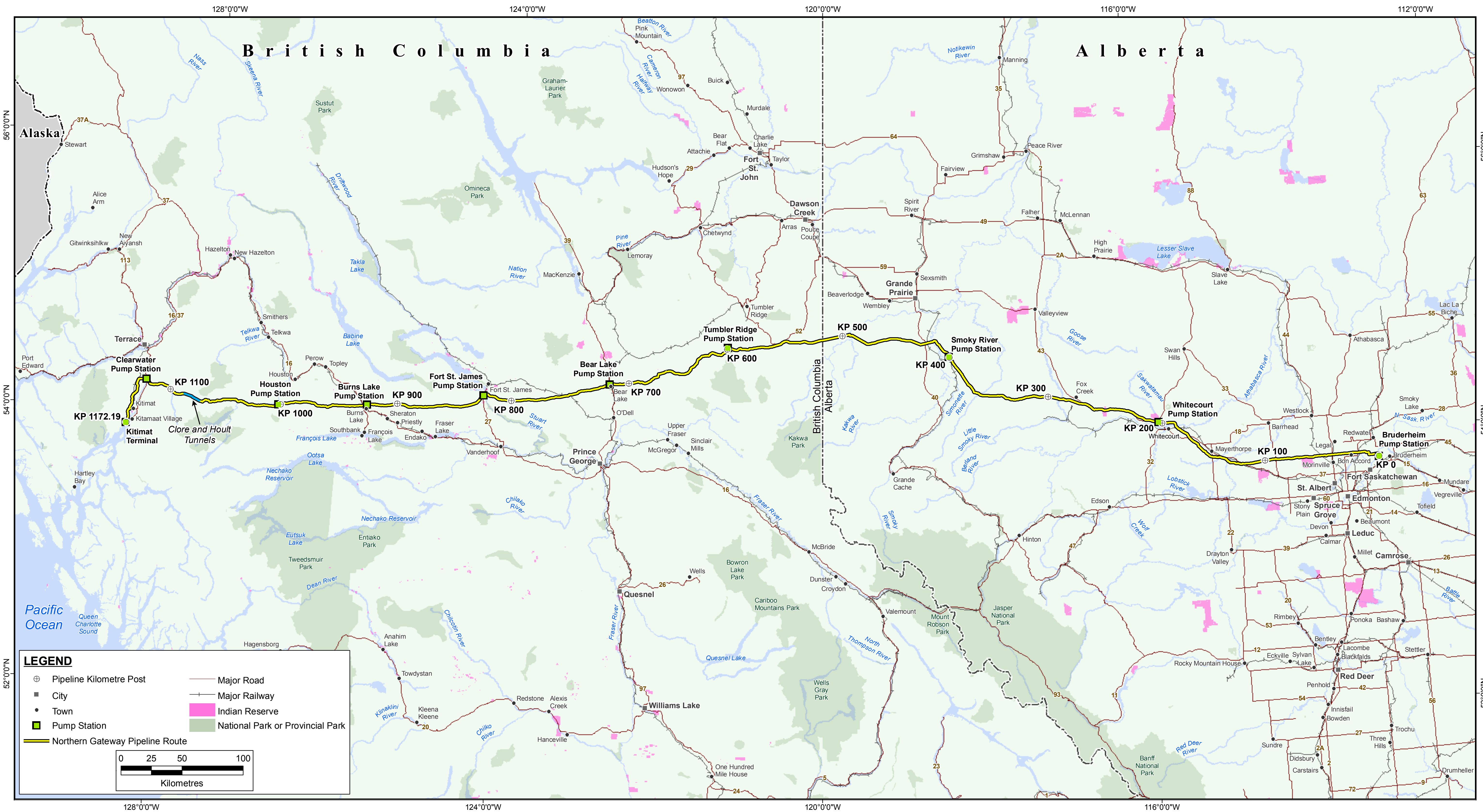
1. Empty, clean and remove all topside equipment.
2. Demolish and remove all piperacks, trestles, gangways, buildings, instrumentation and electrical infrastructure.
3. Dismantle and remove the marine berths and associated concrete and steel pile structures. These facilities will be evaluated for their use as marine habitat prior to removal and may remain for this purpose. Steel piles will be cut off at the sea floor.
4. Tow the utility berth from site for either re-use or recycling.
5. Return the foreshore to its natural state.

14 Abbreviations

API	American Petroleum Institute
ARD	acid rock drainage
ASME	American Society of Mechanical Engineers
ASRD	Alberta Sustainable Resources Development
ASTM	American Society for Testing and Materials
BC	British Columbia
CAPP	Canadian Association of Petroleum Producers
CCME	Canadian Council of Ministers of the Environment
CCO	control centre operations
CGA	Canadian Gas Association
CP	cathodic protection
CSA	Canadian Standards Association
DFO	Fisheries and Oceans Canada
Enbridge	Enbridge Pipelines Inc.
EPMP	Environmental Protection and Management Plan
ESD	emergency shutdown
ESB	electrical services building
GIC	Governor-in-Council
GMAW	gas metal arc welding
GUI	graphical user interface
HDD	horizontal directionally drilled
HHWL	highest high water level
HP	horsepower
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IAPH	International Association of Ports and Harbors
ICS	International Chamber of Shipping
KP	kilometre post
LPM	line pressure monitor
LVP	low vapour pressure
MBS	material balance system
MCC	motor control centre
MOP	maximum operating pressure
MOTEMS	Marine Oil Terminal Engineering and Maintenance Standards
N/A	not applicable
NDE	non-destructive examination
NEB	National Energy Board
NFCC	National Fire Code of Canada
OCIMF	Oil Companies International Marine Forum
OD	outside diameter

OPR .... Onshore Pipeline Regulations
PCV .... pressure control valve
PFD........ process flow diagram
PN........ nominal pressure class
ppm........ parts per million
PPR........ Petroleum Pipeline Regulations
Project........ Enbridge Northern Gateway Project
QA/QC........ quality assurance and quality control
RMF .... risk management framework
RoW .... right-of-way
RTTM........ real time transient model
RTU........ remote terminal unit
SCADA .... supervisory control and data acquisition
SMAW........ shielded metal arc welding
TBM .... tunnel boring machine
UPS........ uninterruptible power supply
UTS .... Universal Transverse Mercator
VFD........ variable frequency drive
VLCC .... very large crude carrier
VRU .... vapour recovery unit

Appendix A Project Overview Map



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Hydrographic Data Source: Geography Division, Statistics Canada, 2006 Boundary Files, 92-160-XWE/F, Major Road and Rail data obtained from Geogratis © Department of Natural Resources Canada. All rights reserved.

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ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT

Overview Map

NGP_B-FIGMAP-L Version: A

Appendix B Tables

Table No.	Title
B-1	Applicable Codes and Standards
B-2	Engineering Standards and Specifications
B-3	NEB Concordance Table - Engineering

Table B-1 Applicable Codes and Standards

Number	Title
Primary Standard	
CSA Z662-07	Oil and Gas Pipeline Systems
NEB OPR-99	Onshore Pipeline Regulations, 1999
API-650	Tanks
Marine	
API RP2A	Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms
BS 6349	British Standard Code of Practice for Marine Structures – Part 1-6
IALA	Aids to Navigation Guide (Navguide) 4th Edition, 2002
California State Lands Commission	Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS), 2006
OCIMF	Design and Construction Specification for Marine Loading Arms, 1999
OCIMF/ICS/IAPH	International Safety Guide for Oil Tankers and Terminals, 2006
OCIMF	Mooring Equipment Guidelines, 2001
OCIMF	Prediction of Wind and Current Loads on VLCCs, 1994
OCIMF	Recommendations for Oil Tanker Manifolds and Associated Equipment, 1991
PIANC	Approach Channels, A Guide for Design, 2004
PIANC	Criteria for Movements of Moored Tankers in Harbors, 2004
PIANC	Guidelines for the Design of Fender Systems, 2004
PIANC	Seismic Design Guidelines for Port Structures, 2004
TERMPOL	Transport Canada – TERMPOL Review Process, 2001
US ARMY	US Army Corps of Engineers, Coastal Engineering Manual, 2002

NOTES
IALA – International Association of Marine Aids to Navigation and Lighthouse Authorities
OCIMF – Oil Companies International Marine Forum
ICS – International Chamber of Shipping
IAPH – International Association of Ports and Harbors

Table B-2 Enbridge Pipelines Inc. Engineering Standards and Specifications

Number	Title
D01-101	Use of Engineering Standards Rev. Jan 2005
D01-102	Policy and Style for Engineering Standards Rev. Oct 20, 2008
D02-101	Design basis, Electrical Rev. Jul 20, 2006
D02-102	Design Basis, Main Line Rev. Aug 01, 2007
D02-103	Design Basis, Station and Terminal Rev. Jan 9, 2007
D02-104	Hazardous Area Classification Rev. Nov 16, 2006
D02-105	Fire Protection, Extinguishment Rev. Jan 6, 2000
D02-106	Noise and Acoustic Dampening Rev. Sep 1, 1999
D02-107	Station Manual, Preparation Rev. Sep 01, 1999
D03-101	Pipeline Corrosion Assessment Rev. Sep 01, 1999
D03-102	Integrity Assessment, Oil Tank Rev. Jul 16, 2001
D03-103	Internal Inspection, Main Line Rev. Sep 01, 1999
D03-104	Weld Inspection Rev. Jan 06, 2000
D03-105	Shop Inspection Rev. Sep 1, 1999
D04-101	Cathodic Protection Rev. Apr 20, 2006
D04-102	Painting, Coating and Lining Rev. Jul 28, 2006
D05-101	Berm, Containment Rev. Nov 6, 2008
D05-102	Site Preparation, Earthwork, Grading, Road and Pavement Rev. Sep 1, 1999
D05-103	Trenches, Underground Lines Rev. Sep 1, 1999
D05-201	Foundation, Oil Storage Tank Rev. Sep 01, 1999
D05-202	Foundation, Station and Terminal Rev. Sep 1, 1999
D05-301	Building, Station and Terminal Rev. June 10, 2009
D05-302	Laboratory, Sample & Sample Storage Buildings Rev. Sep 01, 1999
D05-401	Platforms, Stairs and Ladders Rev. Apr 29, 2003
D06-101	Piping Design and Construction, Main Line, Dec 13, 2006
D06-102	Piping Design, Station and Terminal Rev. May 1, 2008
D06-103	Crossing Design, Main Line Rev. Dec 13, 2006
D06-104	Pipe and Fittings, Steel Rev. Aug 1, 2007
D06-105	Valve, Steel Rev. Jun 15, 2000
D06-105TB	B Valve Application Table Rev. Jan. 4, 2008
D06-106	Piping Design and Construction, Auxiliary Rev. Jan. 18, 2008
D07-101	Pump, Main Line Rev. Nov. 15, 1999
D07-102	Pump, Booster Rev. Nov 15, 1999
D07-201	HVAC, Building, Station & Terminal Rev. Dec. 18, 2009
D07-202	Heat Tracing Rev. Nov 15, 1999

Table B-2 Enbridge Pipelines Inc. Engineering Standards and Specifications (cont'd)

Number	Title
D07-203	HVAC, Pipeline Maintenance Building Rev. Nov 15, 1999
D07-301	Sump System Design Rev. Nov. 15, 1999
D07-302	Flare Stacks & Pits Rev. Nov 15, 1999
D08-101	Oil Storage Tank Rev. Feb 26, 2008
D08-102	Oil Storage Tank Roof Rev. Nov. 15, 1999
D08-103	Oil Storage Tank, Accessories Rev. Nov 15, 1999
D09-104	Custody Transfer Metering Systems, Mar 19, 2008
D10-101	Power System Design Rev. Oct 29, 2002
D10-102	Substation Design Rev. Dec 01, 1999
D10-103	Switchgear & Motor Control Center Rev. May 03, 2007
D10-104	Auxiliary Power Supplies Rev. Dec 1, 1999
D10-105	Power System Protective Relaying Rev. Apr 18, 2007
D10-106	Substation Grounding Rev. Dec 01, 1999
D10-107	Surge Protection & Insulation Coordination Rev. Dec 1, 1999
D10-201	Wiring Methods Rev. Jul 20, 2006
D10-202	Grounding Methods Rev, Dec 1, 1999
D11-101	Motor, Main Line Pump Rev. Dec 01 1999
D11-102	Variable Frequency Drive Rev. June 11, 2008
D11-103	Motor Protection Rev. Dec 01, 1999
D11-201	Lighting, Indoor Rev. Dec 01, 1999
D11-202	Lighting, Outdoor Rev. Dec 01, 1999
D11-301	Valve Actuation and Control Rev. Jan 11, 2007
D12-101	Control, Pump Station Rev. Jul 20, 2006
D12-102	Control, Injection & Delivery Facility Rev. Jul 20, 2006
D12-104	Pressure Relief Rev. Oct 02, 2003
D12-201	Instrumentation, General Rev. Nov 26, 2002
D12-202	Gas Detection Rev. Dec 01, 1999
D12-203	Fire Detection Rev. Dec 01, 1999
D12-204	Vibration Monitoring Rev. Dec. 01, 1999
D12-205	Programmable Logic Controllers Rev. Jan 04, 2008
D12-208	Pressure Control System Rev. Feb 21, 2006

Table B-2 Enbridge Pipelines Inc. Engineering Standards and Specifications (cont'd)

Number	Title
Specifications for Facility Construction (Canada)	
Section 01	Site Preparation Rev. Mar 14, 2003
Section 02	Piping and Electrical Rev. Mar. 14, 2003
Section 03	Sewers and Drains. Rev. Mar 14, 2003
Section 04	Roads and Asphalt Paving Rev. Mar 14, 2003
Section 05	Grouting Rev. Dec 5, 2008
Section 06	Concrete Rev. Mar 14, 2003
Section 07	Concrete Piles Rev. Mar 14, 2003
Section 08	Steel Pipe Piles Rev. June 26, 2009
Section 09	Precast Concrete Piles Rev. Mar 14, 2003
Section 10	Electrical Rev. Mar 14, 2003
Section 11	Instrument Rev. Mar 14, 2003
Section 12	Station Piping Rev. April 30, 2009
Section 13	Piping Classes Rev. Aug 1, 2007
Section 14	Pressure Testing Facility Piping Rev. Aug. 17, 2009
Section 15	Mechanical Equipment Installation Rev. Aug. 11, 2009
Section 16	PE & PVC Pressure Piping Rev. Mar 14, 2003
Section 17	Coatings Rev. Mar 14, 2003
Section 18	Structural Steel Rev. Sept. 14, 2009
Section 19	Painting Rev. Mar. 14, 2003
Section 20	Preservation of Mechanical Equipment Aug. 7, 2009

Table B-3 NEB Filing Manual Concordance Table - Engineering

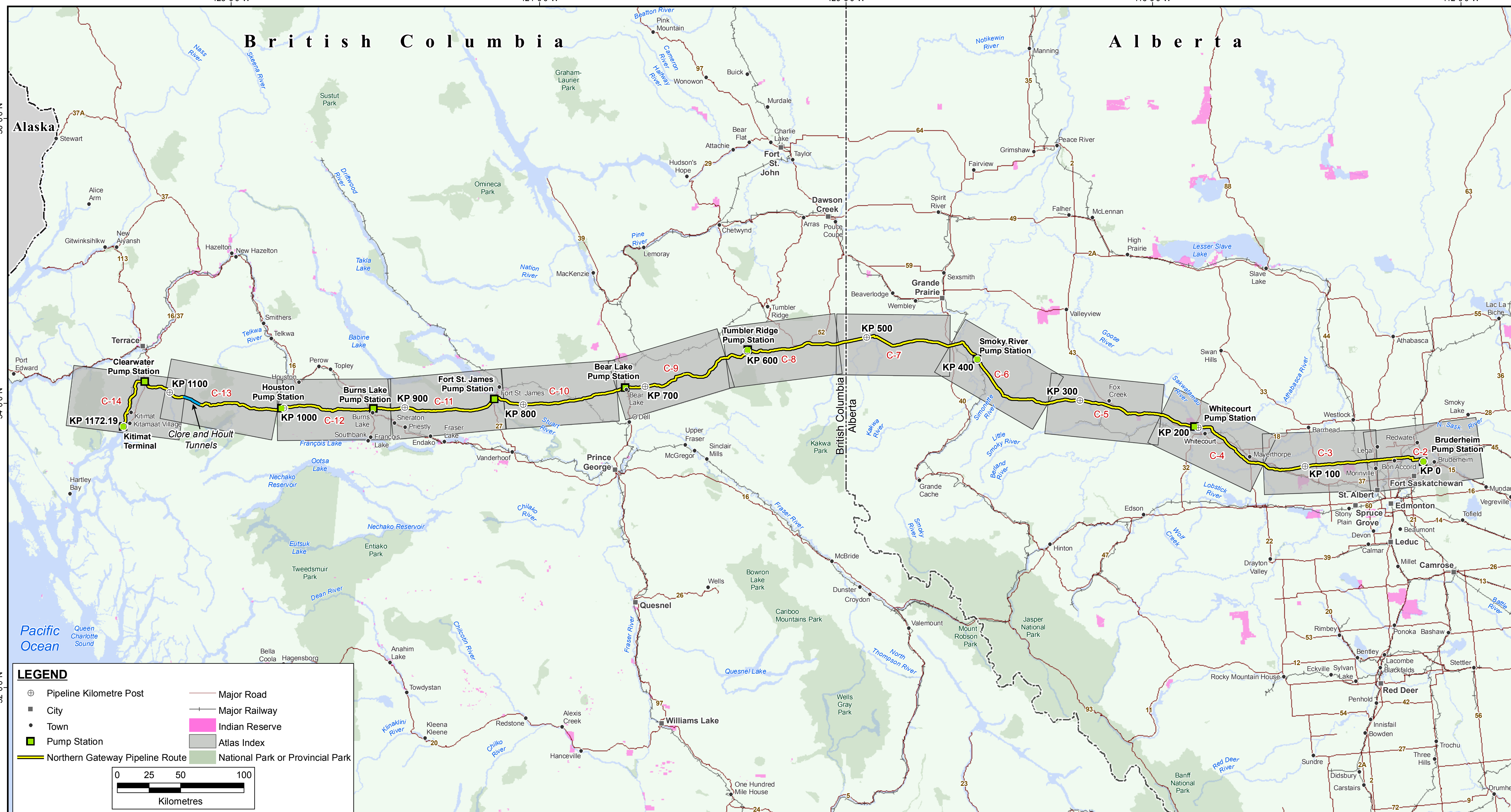
Filing No.	Topic	Location in Volume 3
A.1.1 Engineering Design Details		
1.	Fluid type and composition.	Section 4.2.2, Table 4-2 Section 4.3.2, Table 4-5
2.	Line pipe specifications.	Section 5.1, Table 5-1, Table 5-2
3.	Pigging [scraper trap] facilities specifications.	Section 5.6, Table 5-3, Table 5-4
4.	Compressor or pump facilities specifications.	Section 8.3, Table 8-1
5.	Pressure regulating or metering facilities specifications.	Section 9.1.5 Section 9.1.7 Section 9.2.3 Section 9.2.6
6.	Liquid tank specifications.	Section 9.1.3, Table 9-1 Section 9.1.6, Table 9-2 Section 9.2.4, Table 9-5
7.	New control system facilities specifications.	Section 11.1 Section 11.2 Section 11.3 Section 11.4
8.	Gas processing, sulphur or LNG plant facilities specifications.	No such facilities
9.	Technical description of other facilities not mentioned above.	No such facilities
10.	Building dimensions and uses.	Section 8.7, Table 8-3 Section 9.3, Table 9-8
11.	If project is a new system that is a critical source of energy supply, a description of the impact to the new system capabilities following loss of critical component.	Not a critical energy supply because the Project is designed to serve the export market

Table B-3 NEB Concordance Table – Engineering (cont'd)

Filing No.	Topic	Location in Volume 3
A.1.2 Engineering Design Philosophy		
1.	Confirmation project activities will follow the requirements of the latest version of CSA Z662.	Section 1.4 Section 1.6.1
2.	Statement confirming compliance with OPR or PPR.	Section 1.4 Section 1.6.1
3.	Listing of all primary codes and standards, including version and date of issue.	Section 1.4 Appendix B, Table B-1
4.	Confirmations that the project will comply with company manuals and confirm manuals comply with OPR/PPR and codes and standards.	Section 1.4 Section 1.6.1 Section 1.6.3 Appendix B, Table B-1, Table B-2
5.	Any portion of the project a non-hydrocarbon commodity pipeline system? Provide a QA program so that the materials are appropriate for their intended service.	All products are hydrocarbon liquids
6.	If facility subject to conditions not addressed in CSA Z662: Written statement by qualified professional engineer Description of the designs and measures required to safeguard the pipeline	Section 5.14, Table 5-7
7.	If directional drilling involved: Preliminary feasibility report Description of the contingency plan	Section 6.3.2
A.1.3 Onshore Pipeline Regulations		
1.	Designs, specifications programs, manuals, procedures, measures or plans for which no standard is set out in the OPR.	Existing standards will be followed
2.	A quality assurance program if project non-routine or incorporates unique challenges due to geographical location.	No unique challenges
3.	If welding performed on a liquid-filled pipeline that has a carbon equivalent of 0.50% or greater and is a permanent installation: Welding specifications and procedures Results of procedure qualification tests	Welding on liquid filled pipe will not be conducted

Appendix C Pipeline Route Atlas

No.	Title
C-1	Pipeline Route Atlas Index
C-2	Pipeline Route Atlas – Kilometre Posts 0 to 55
C-3	Pipeline Route Atlas – Kilometre Posts 55 to 135
C-4	Pipeline Route Atlas – Kilometre Posts 135 to 235
C-5	Pipeline Route Atlas – Kilometre Posts 235 to 330
C-6	Pipeline Route Atlas – Kilometre Posts 330 to 430
C-7	Pipeline Route Atlas – Kilometre Posts 430 to 525
C-8	Pipeline Route Atlas – Kilometre Posts 525 to 625
C-9	Pipeline Route Atlas – Kilometre Posts 625 to 725
C-10	Pipeline Route Atlas – Kilometre Posts 725 to 820
C-11	Pipeline Route Atlas – Kilometre Posts 820 to 915
C-12	Pipeline Route Atlas – Kilometre Posts 915 to 1005
C-13	Pipeline Route Atlas – Kilometre Posts 1005 to 1105
C-14	Pipeline Route Atlas – Kilometre Posts 1105 to 1172



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National Parks & Indian Reserves: NRCan CLAB Lv1 (May 2009); AB Provincial Parks: TPR, AB Government (Sept. 2008); BC Provincial Parks: ILMB, BC Government (May 2009).
Hydrographic Data Source: Geography Division, Statistics Canada, 2006 Boundary Files, 92-160-XWE/F, Major Road and Rail data obtained from Geogratis © Department of Natural Resources Canada. All rights reserved.

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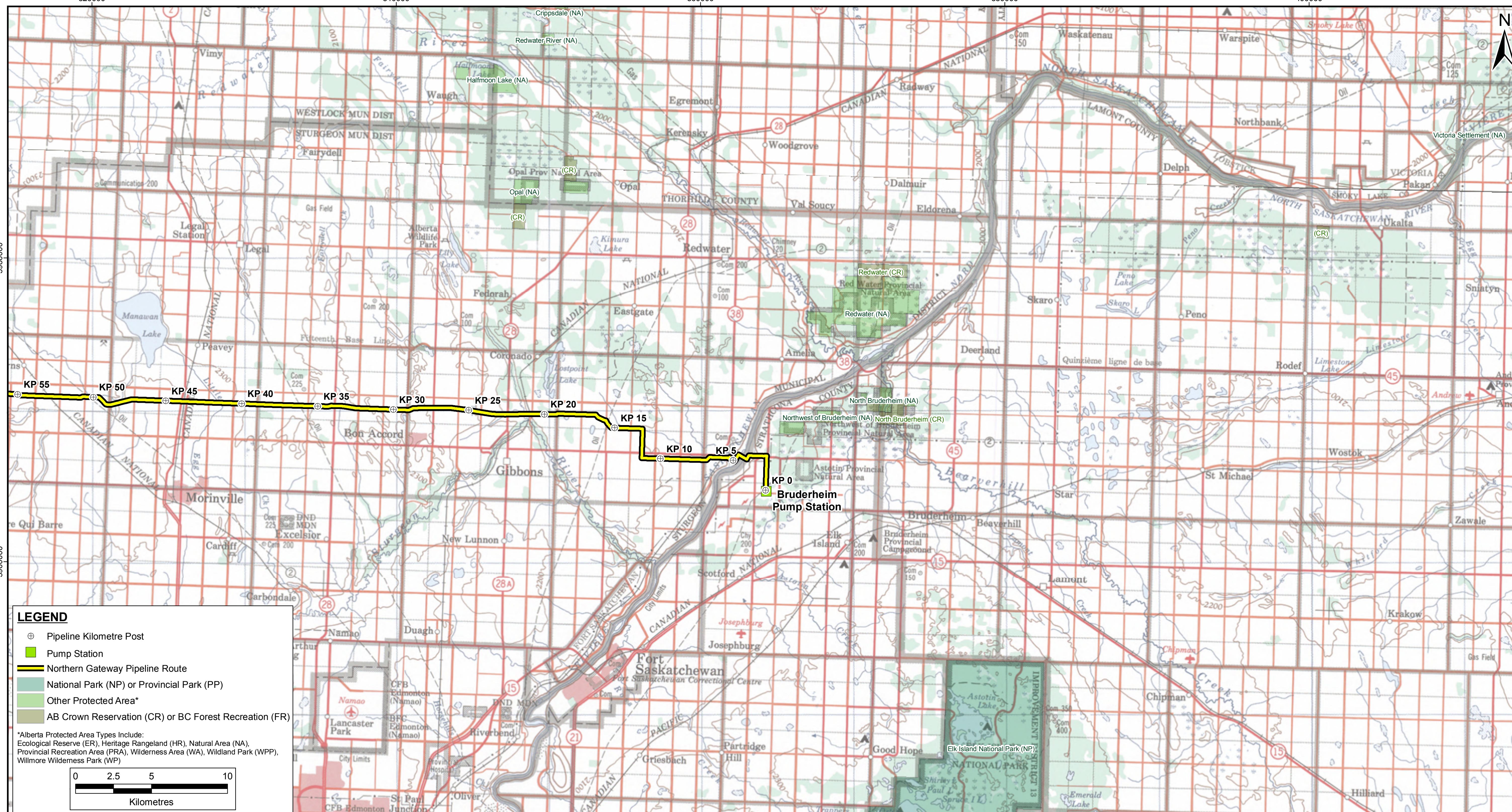
ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT

Pipeline Route Atlas Index

FIGURE NO. C-1

NGP_B-FIGMAP-L Version: A



WorleyParsons resources & energy	REFERENCES Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. UTM 12N Projection and NAD 83 Datum. National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009). © Topographic map reproduced under licence from Her Majesty the Queen in Right of Canada, with permission of Natural Resources Canada.
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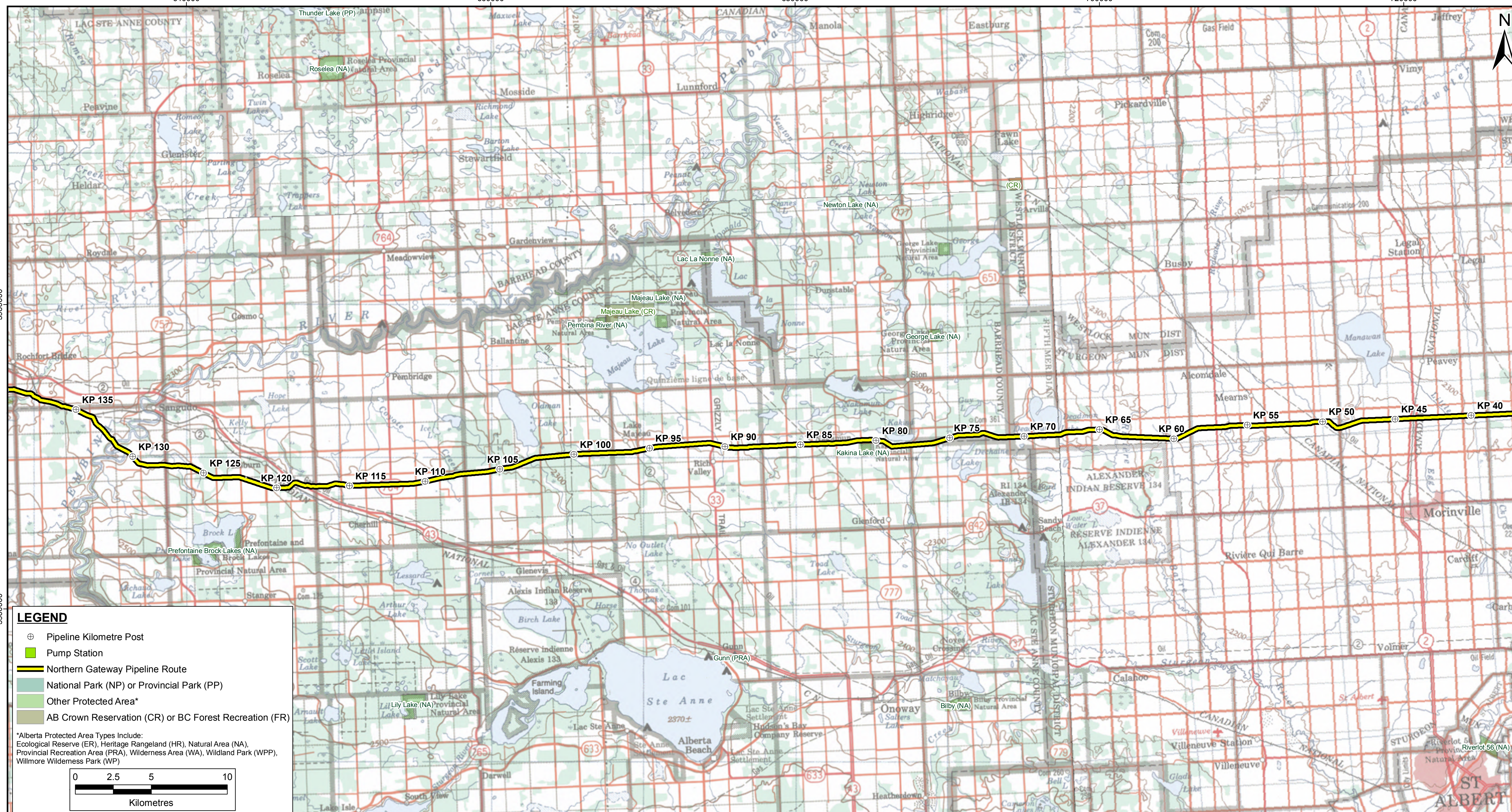
	Pipeline Route Atlas - Kilometre Posts 0 to 55

SCALE	1:250,000
DATE	13 Aug 2009
FIGURE ID	11-025-001
REVISION	A
FIGURE NO.	C-2

NGP_B-FIGMAP-L Version: A



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REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. UTM 11N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE	1:250,000
DATE	13 Aug 2009
FIGURE ID	11-025-002
REVISION	A

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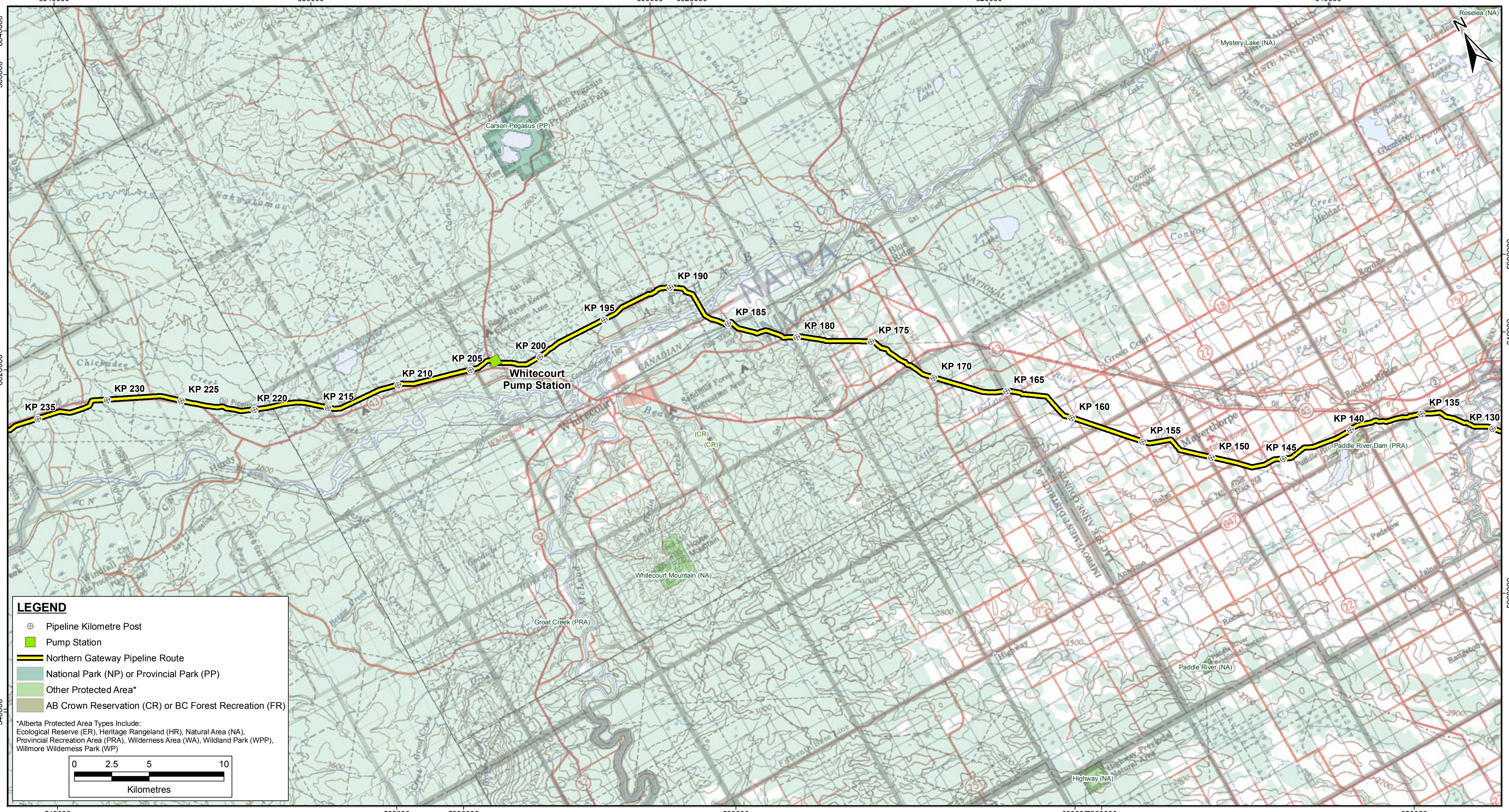
Pipeline Route Atlas - Kilometre Posts 55 to 135

FIGURE NO.
C-3

NGP_B-FIGMAP-L Version: A



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REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. UTM 11N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE	1:250,000
DATE	13 Aug 2009
FIGURE ID	11-025-003
REVISION	A
FIGURE NO.	C-4

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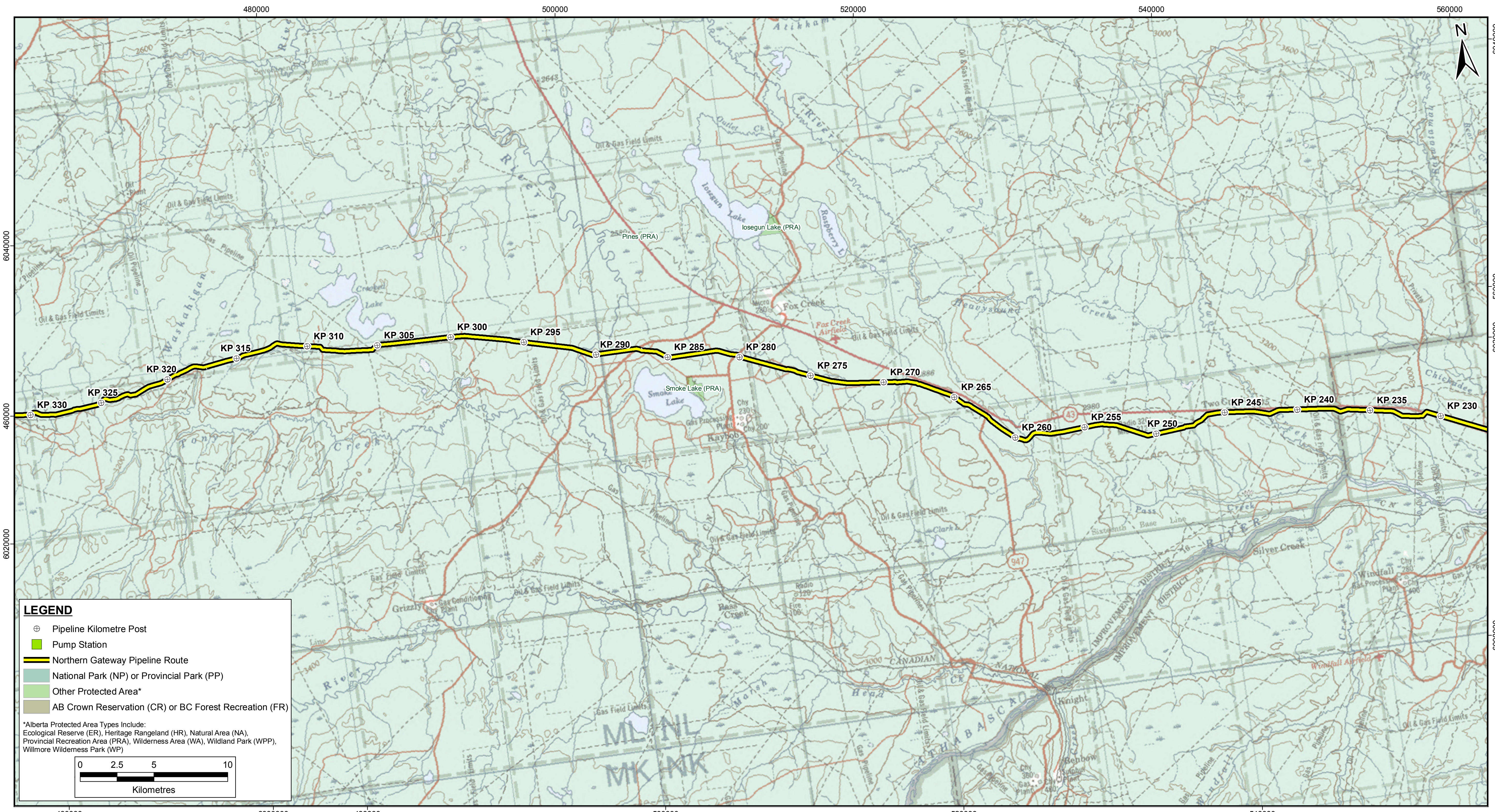
Pipeline Route Atlas - Kilometre Posts 135 to 235

NGP_B-FIGMAP-L Version: A



WorleyParsons
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REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. UTM 11N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE	1:250,000
DATE	13 Aug 2009
FIGURE ID	11-025-004
REVISION	A
FIGURE NO.	C-5

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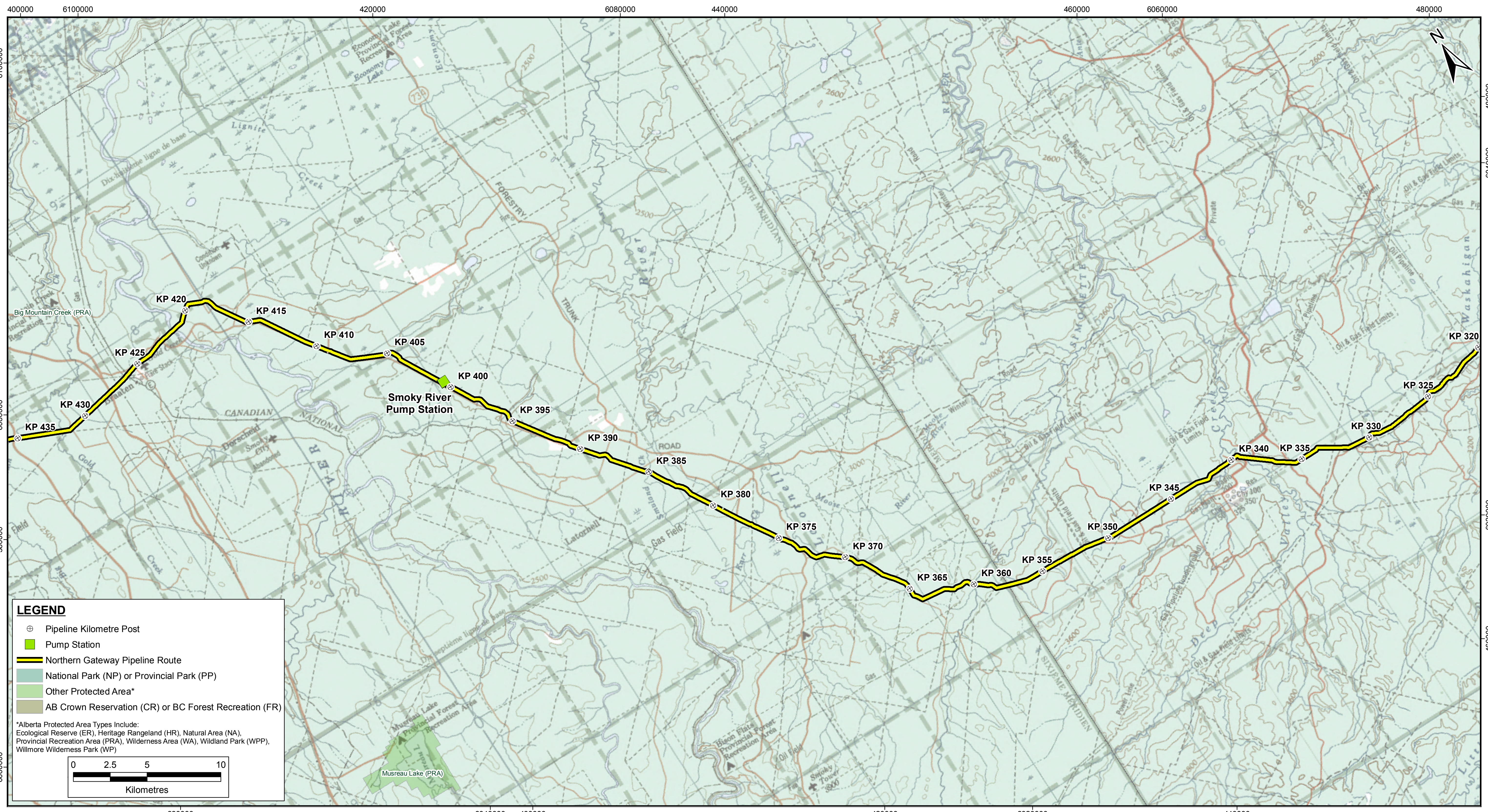
Pipeline Route Atlas - Kilometre Posts 235 to 330

NGP_B-FIGMAP-L Version: A



REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. UTM 11N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

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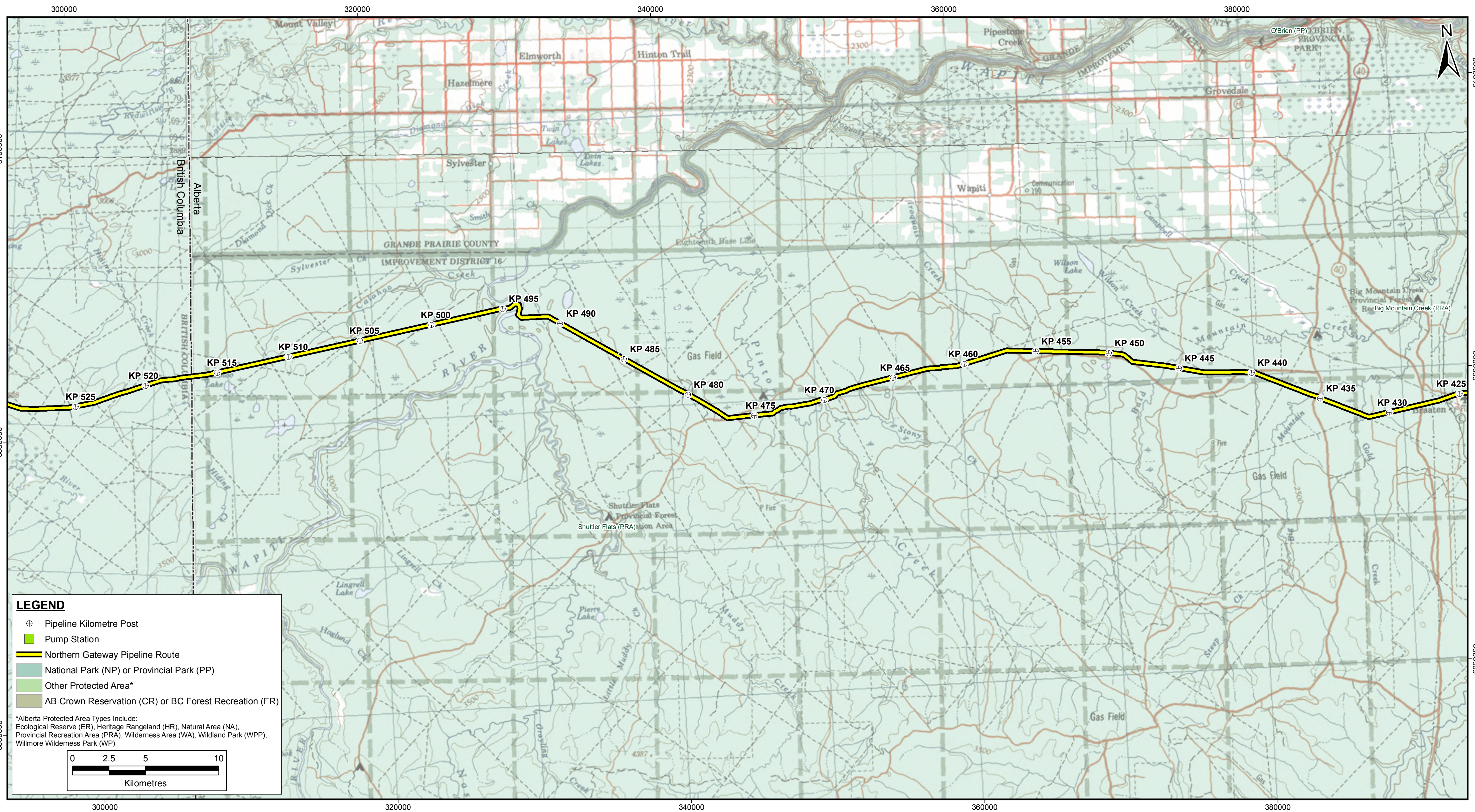
Pipeline Route Atlas - Kilometre Posts 330 to 430

SCALE	1:250,000
DATE	13 Aug 2009
FIGURE ID	11-025-005
REVISION	A
FIGURE NO.	C-6

NGP_B-FIGMAP-L Version: A



WorleyParsons resources & energy

REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. UTM 11N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE	1:250,000
DATE	17 Aug 2009
FIGURE ID	11-025-006
REVISION	A
FIGURE NO.	C-7

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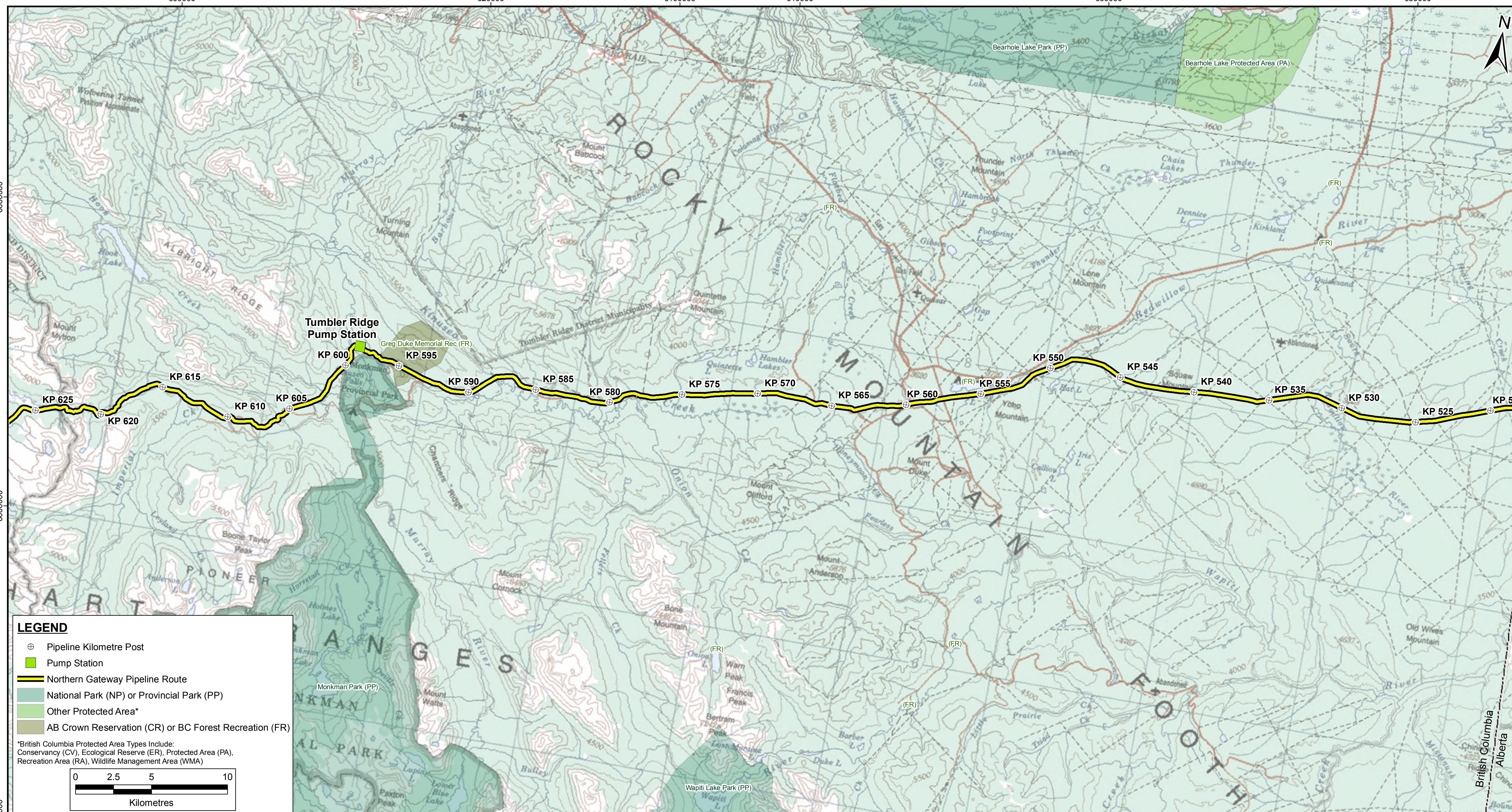
Pipeline Route Atlas - Kilometre Posts 430 to 525

NGP_B-FIGMAP-L Version: A



WorleyParsons
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REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. UTM 10N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE	1:250,000
DATE	17 Aug 2009
FIGURE ID	11-025-007
REVISION	A
FIGURE NO.	C-8

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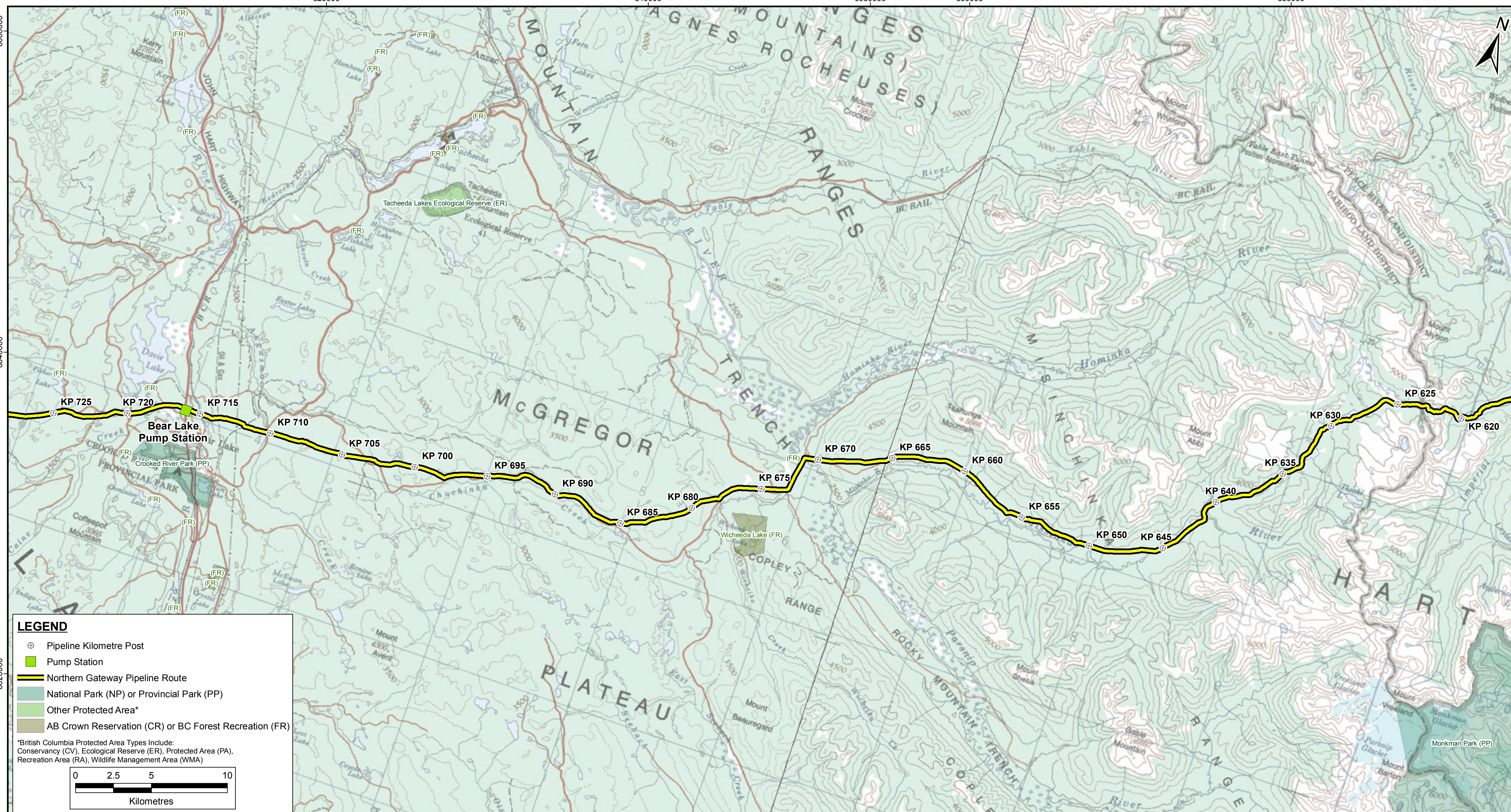
Pipeline Route Atlas - Kilometre Posts 525 to 625

NGP_B-FIGMAP-L Version: A



WorleyParsons
resources & energy

REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. UTM 10N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).
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SCALE	1:250,000
DATE	17 Aug 2009
FIGURE ID	11-025-008
REVISION	A
FIGURE NO.	C-9

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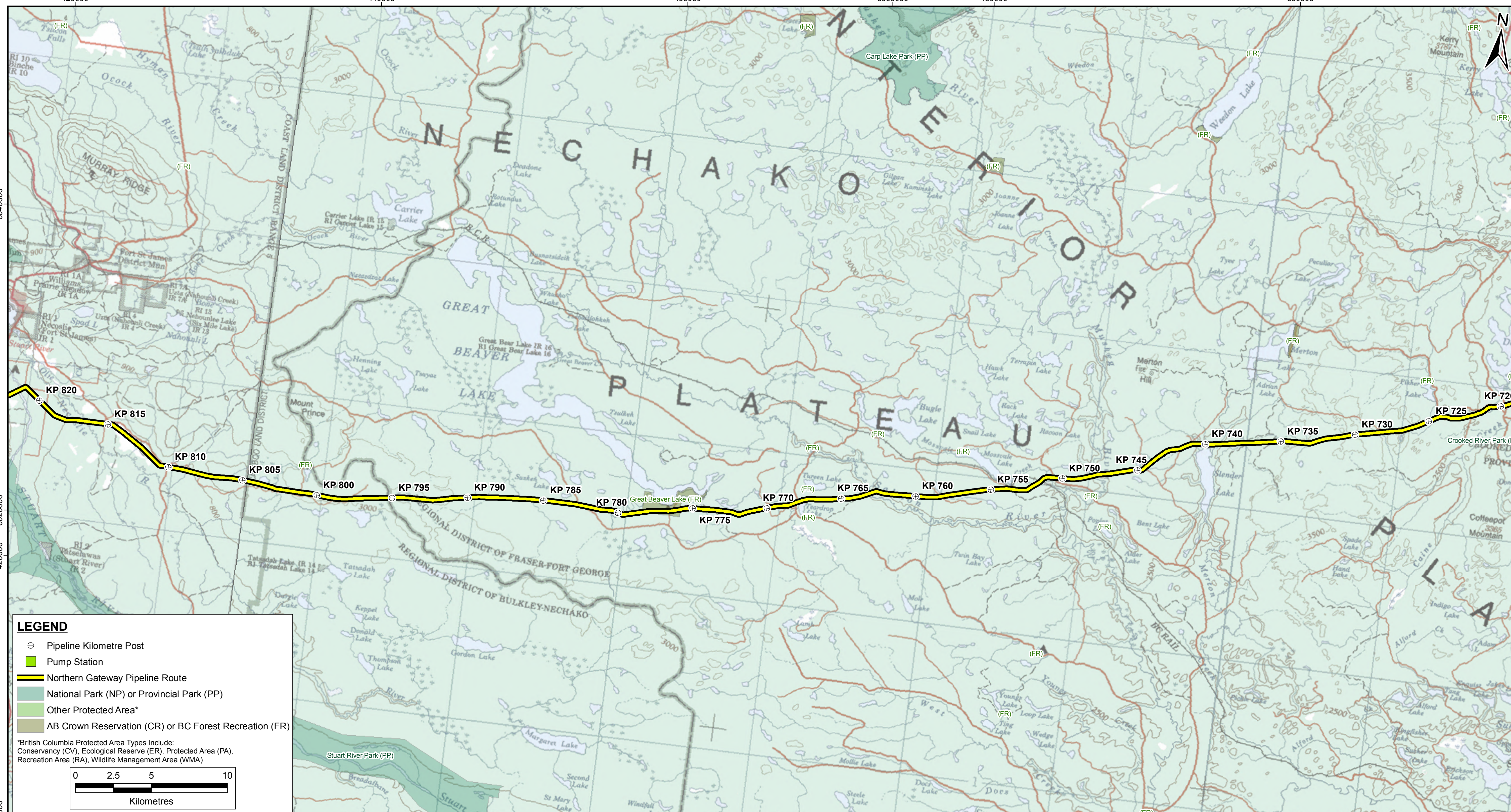
Pipeline Route Atlas - Kilometre Posts 625 to 725

NGP_B-FIGMAP-L Version: A



WorleyParsons resources & energy

REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. UTM 10N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE	1:250,000
DATE	17 Aug 2009
FIGURE ID	11-025-009
REVISION	A
FIGURE NO.	C-10

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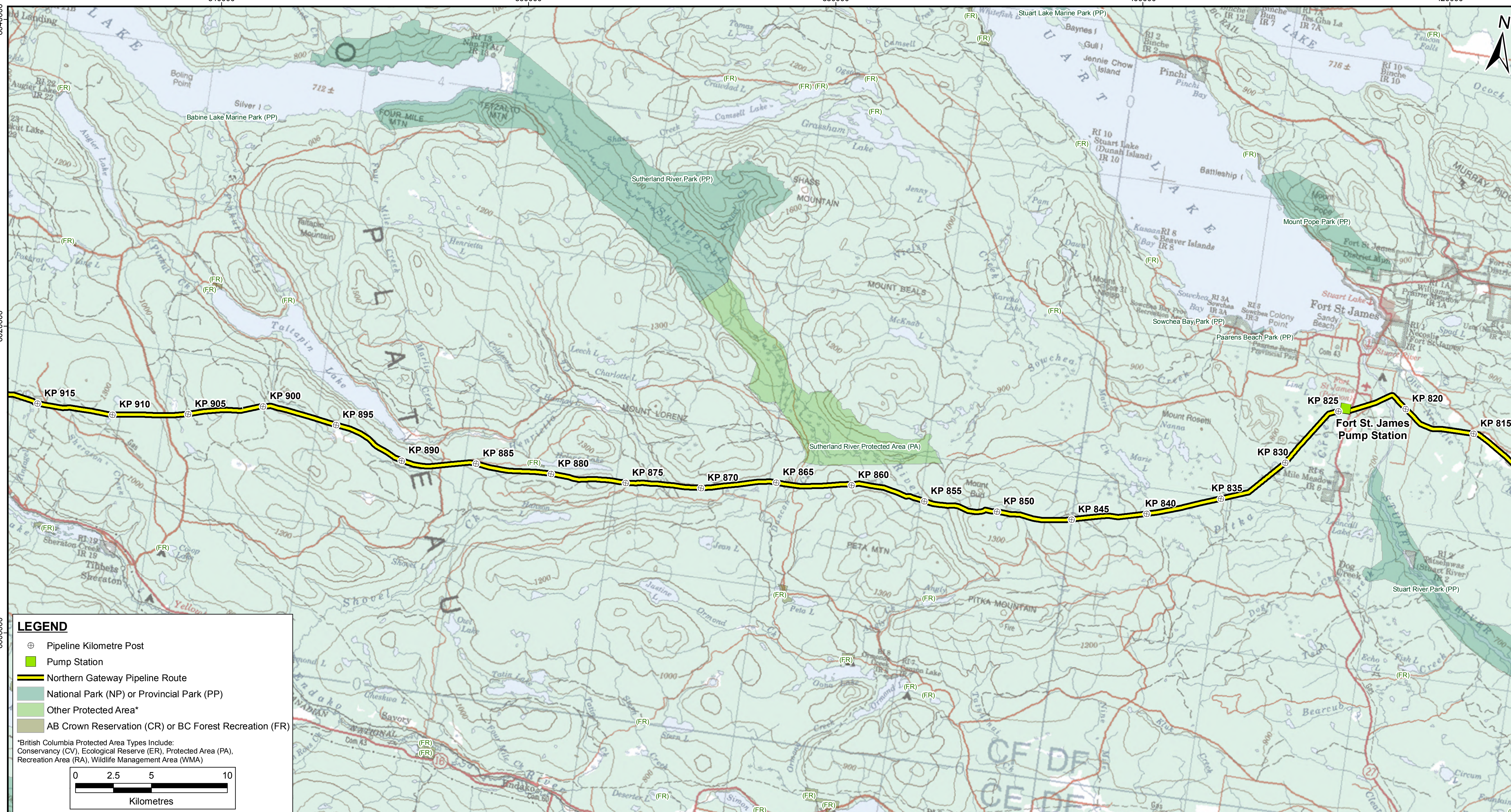
Pipeline Route Atlas - Kilometre Posts 725 to 820

NGP_B-FIGMAP-L Version: A



WorleyParsons resources & energy

REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. UTM 10N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

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NGP_B-FIGMAP-L Version: A

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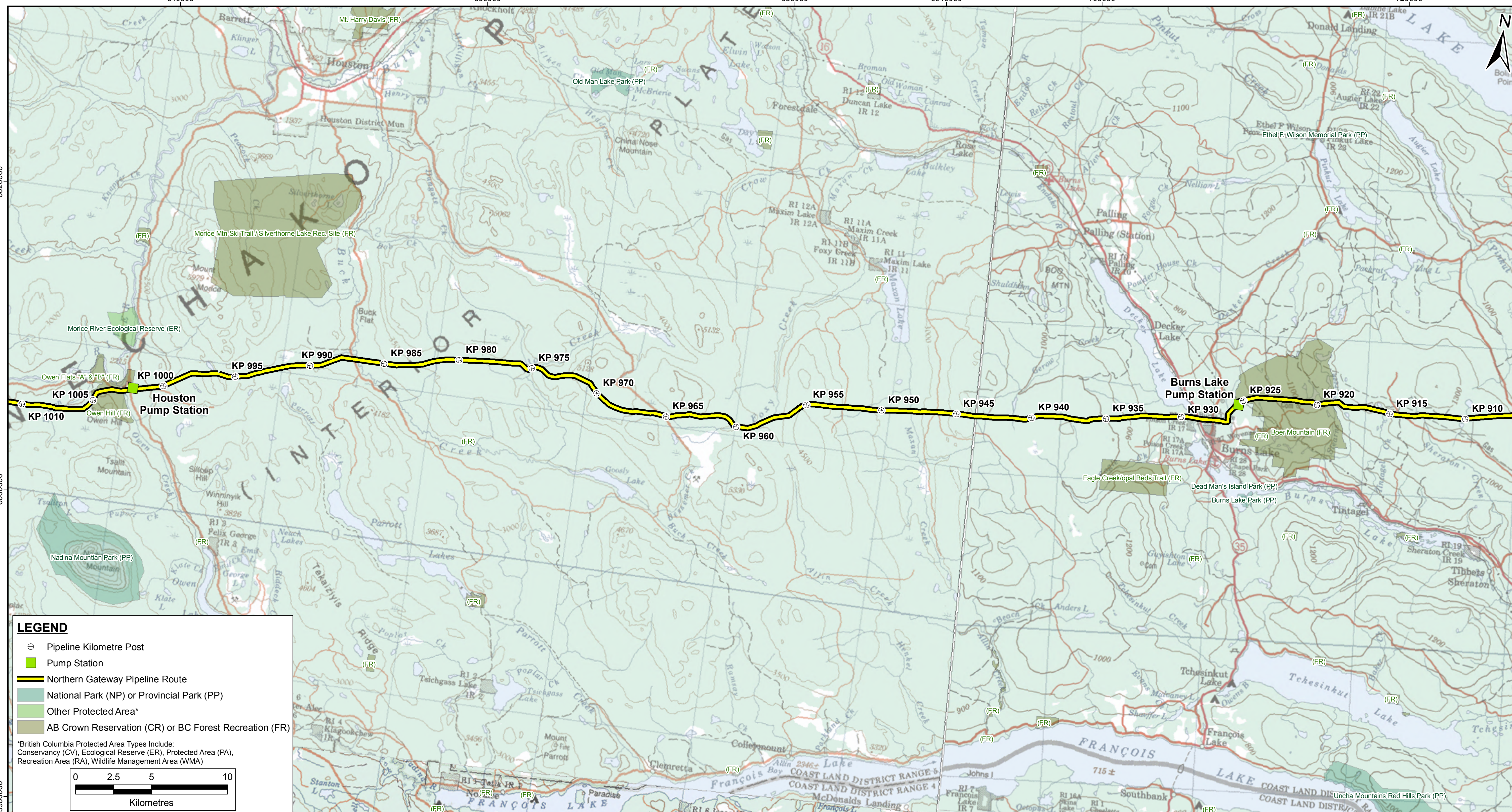
Pipeline Route Atlas - Kilometre Posts 820 to 915

SCALE	1:250,000
DATE	17 Aug 2009
FIGURE ID	11-025-010
REVISION	A
FIGURE NO.	C-11



WorleyParsons resources & energy

REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. UTM 9N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE	1:250,000
DATE	17 Aug 2009
FIGURE ID	11-025-011
REVISION	A
FIGURE NO.	C-12

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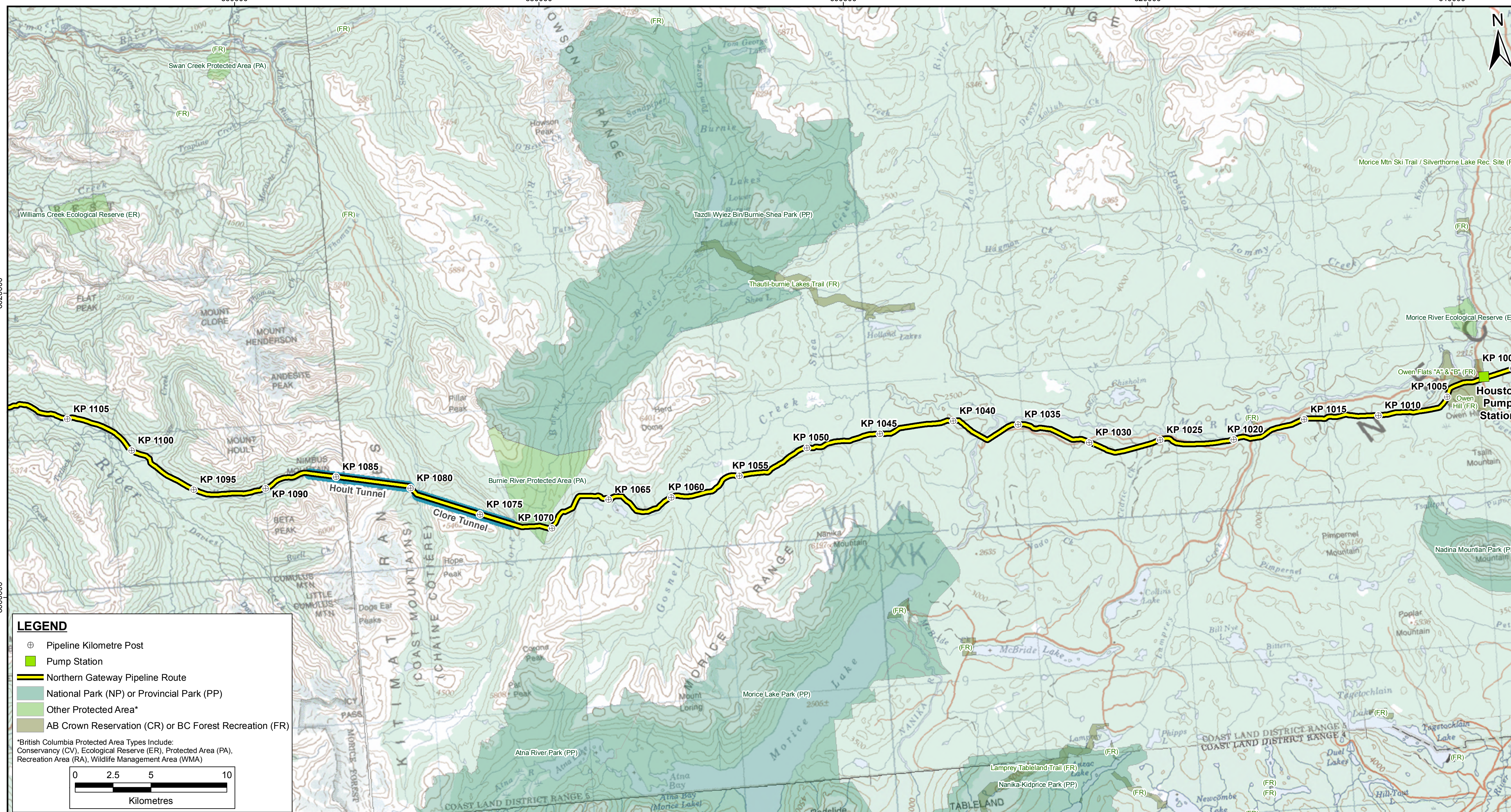
Pipeline Route Atlas - Kilometre Posts 915 to 1005

NGP_B-FIGMAP-L Version: A



REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. UTM 9N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

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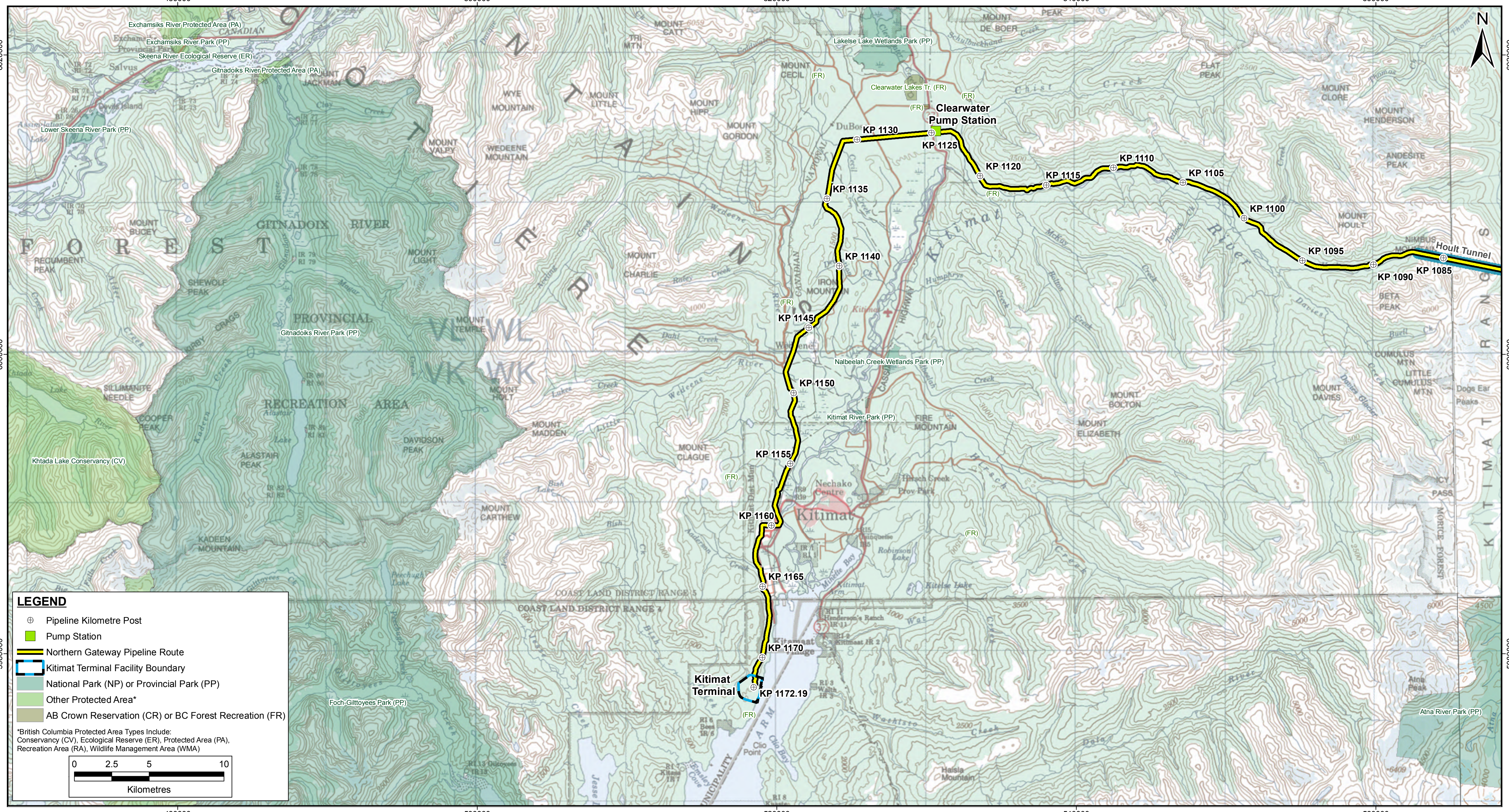
Pipeline Route Atlas - Kilometre Posts 1005 to 1105

SCALE	1:250,000
DATE	17 Aug 2009
FIGURE ID	11-025-012
REVISION	A
FIGURE NO.	C-13

NGP_B-FIGMAP-L Version: A



WorleyParsons resources & energy

REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. UTM 9N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).
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SCALE	1:250,000
DATE	20 Aug 2009
FIGURE ID	11-025-013
REVISION	A
FIGURE NO.	C-14

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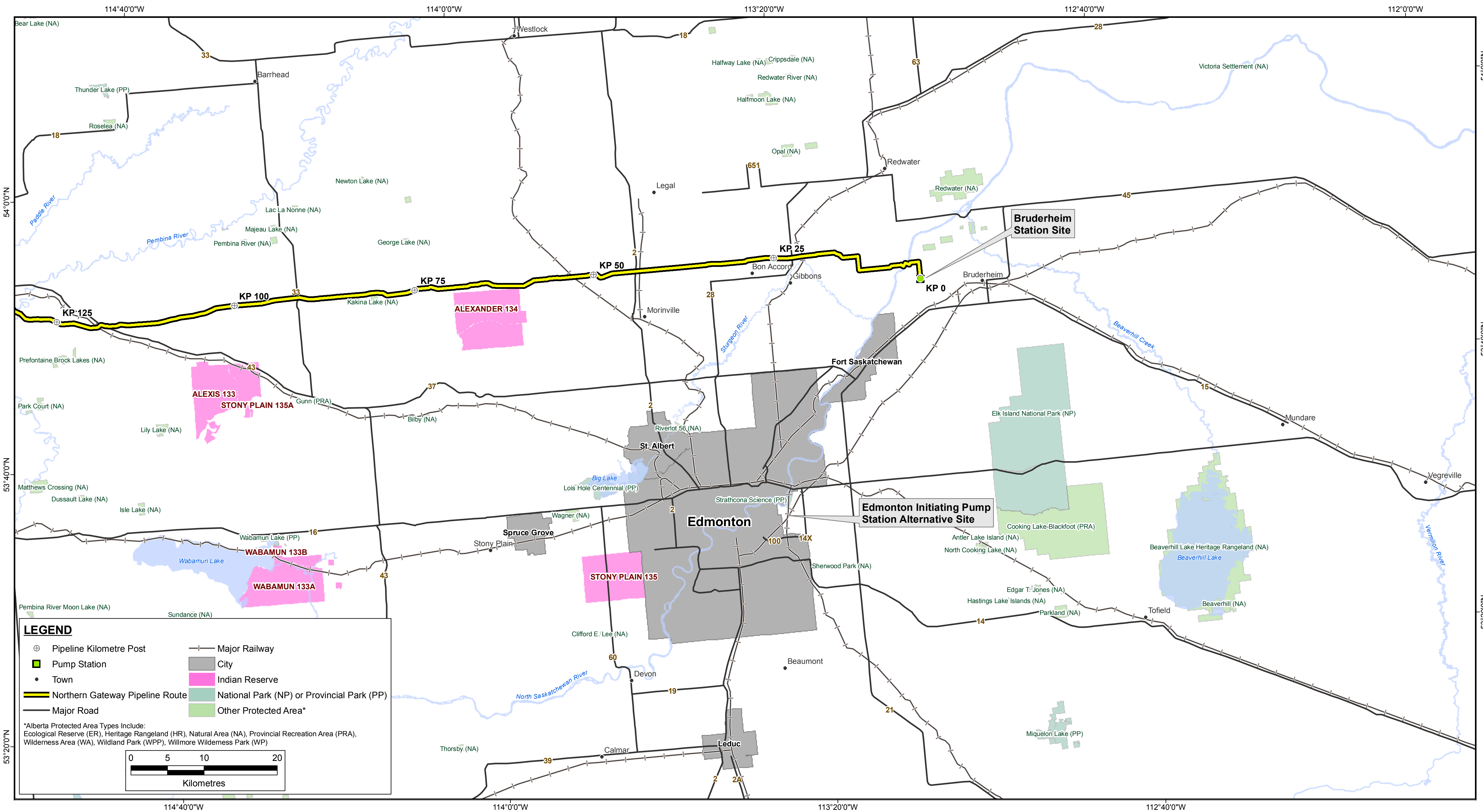
Pipeline Route Atlas - Kilometre Posts 1105 to 1172

NGP_B-FIGMAP-L Version:A

Appendix D Pipeline Route Alternatives

List of Maps	
Map No.	**Description**
D-1	Alternative Sites for Initiating Pump Station
D-2	Alternative Sites for Kitimat Terminal
D-3	Initial Pipeline Route Alternatives
D-4	Pipeline Route Revisions – Kilometre Posts 0 to 20
D-5	Pipeline Route Revisions – Kilometre Posts 186 to 260
D-6	Pipeline Route Revisions – Kilometre Posts 310 to 415
D-7	Pipeline Route Revisions – Kilometre Posts 415 to 475
D-8	Pipeline Route Revisions – Kilometre Posts 475 to 535
D-9	Pipeline Route Revisions – Kilometre Posts 634 to 681
D-10	Pipeline Route Revisions – Kilometre Posts 810 to 833
D-11	Pipeline Route Revisions – Kilometre Posts 915 to 927
D-12	Pipeline Route Revisions – Kilometre Posts 955 to 1042
D-13	Pipeline Route Revisions – Kilometre Posts 1067 to 1161



WorleyParsons resources & energy

REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary. LCC Projection (Central Meridian 120W, Standard Parallels 52N & 56N) and NAD 83 Datum.
National Parks & Indian Reserves: NRCan CLAB Lv1 (May 2009); AB Provincial Parks & Protected Areas: TPR, AB Government (Sept. 2008); City and Town Locations provided by IHS Inc. (June 2008).
Hydrographic Data Source: Geography Division, Statistics Canada, 2006 Boundary Files, 92-160-XWE/F, Major Road and Rail data obtained from Geogratis © Department of Natural Resources Canada. All rights reserved.

SCALE 1:500,000

DATE 17 Aug 2009

FIGURE ID 11-026-001

REVISION A

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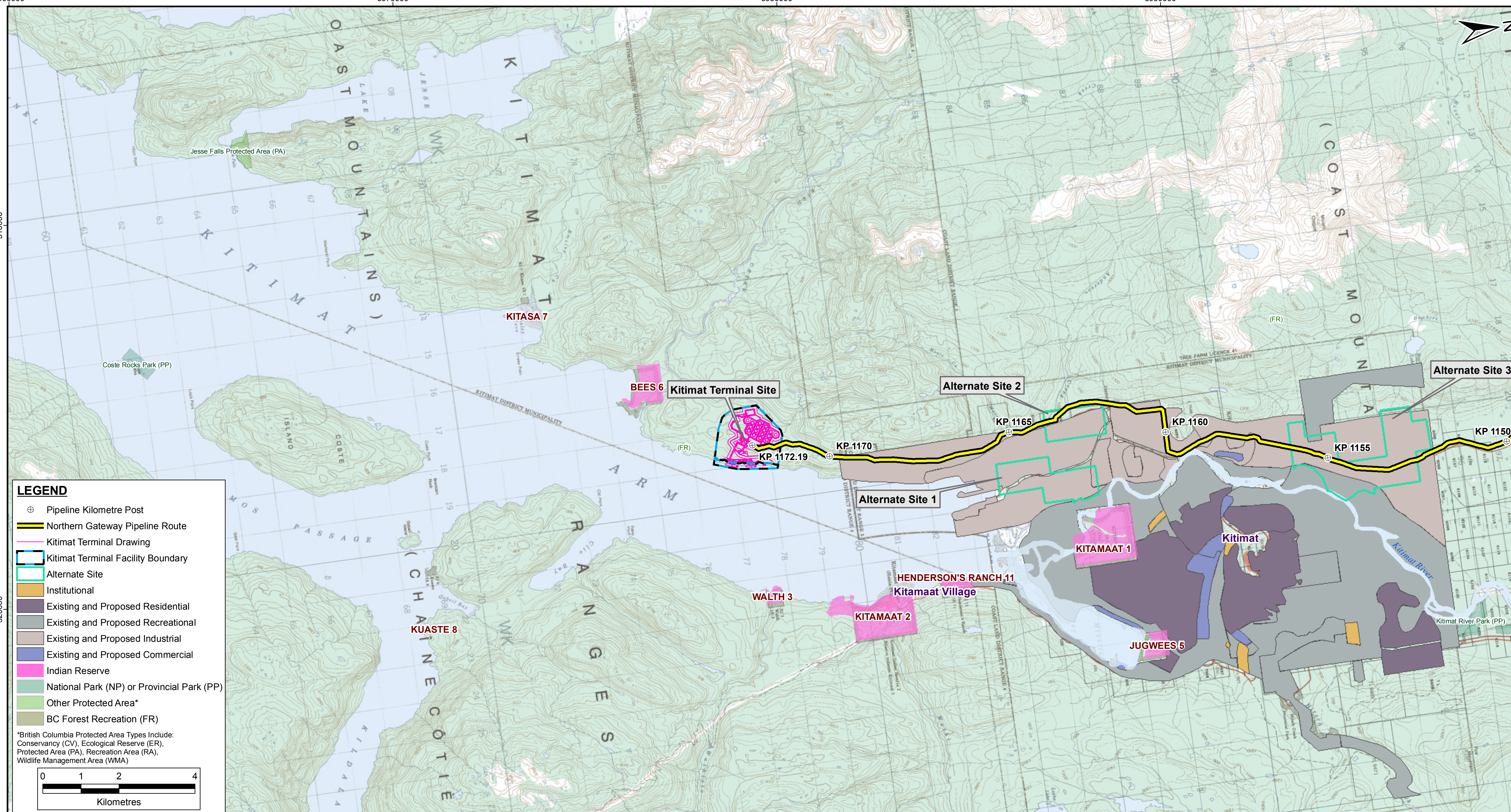
ENBRIDGE NORTHERN GATEWAY PROJECT

Alternative Sites for the Initiating Pump Station

FIGURE NO. **D-1**

NGP_B-FIGMAP-L Version: A



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REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary., Facility Boundary and Kitimat Terminal Drawing, 2008 provided by WorleyParsons Calgary. UTM 9N Projection and NAD 83 Datum.
National Parks & Indian Reserves: NRCan CLAB Lv1 (May 2009); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).
Hydrographic Data Source: Geography Division, Statistics Canada, 2006 Boundary Files, 92-160-XWE/F., © Topographic map reproduced under licence from Her Majesty the Queen in Right of Canada, with permission of Natural Resources Canada.

SCALE	1:100,000
DATE	17 Aug 2009
FIGURE ID	11-026-002
REVISION	A
FIGURE NO.	D-2

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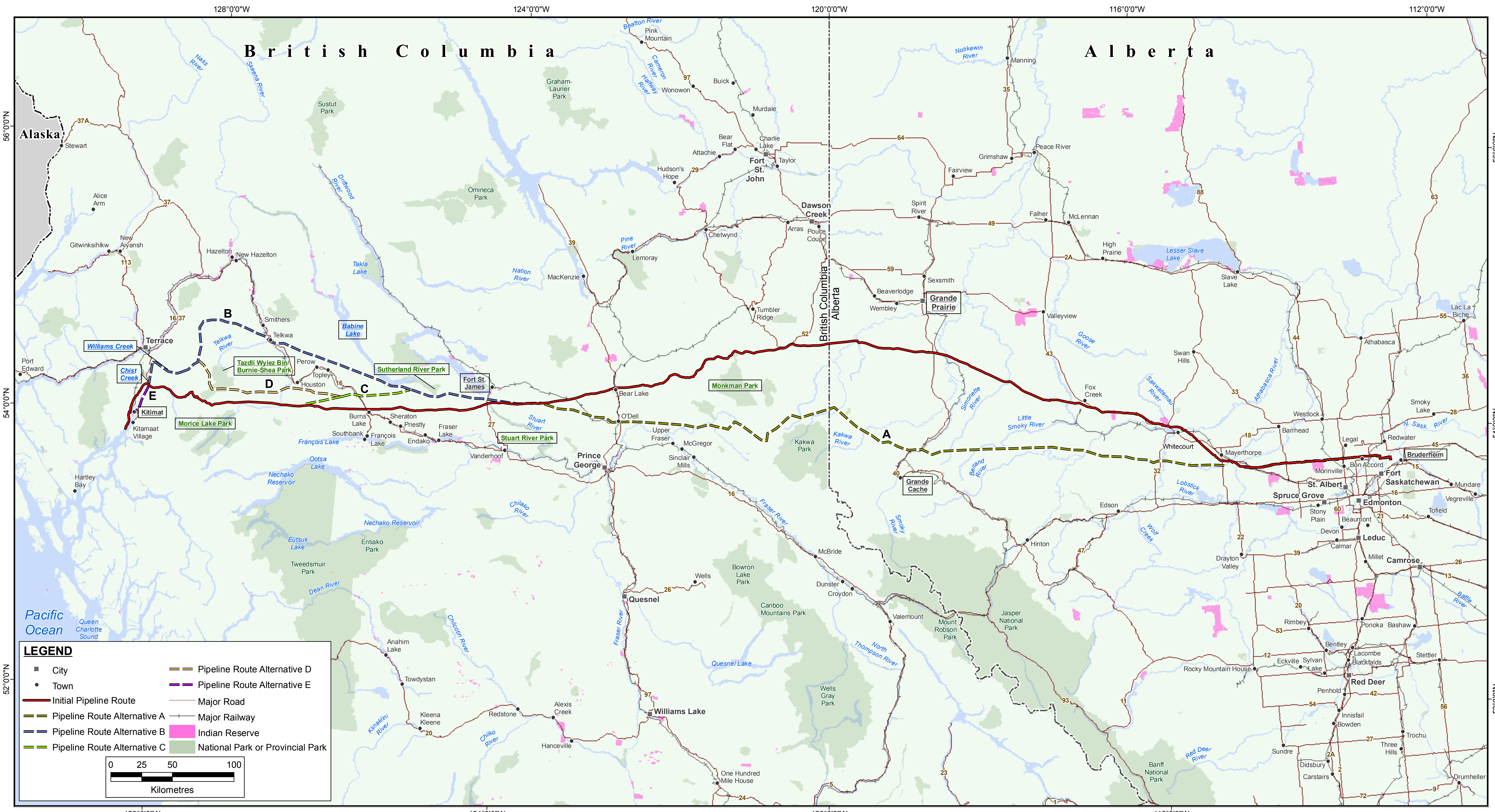
Alternative Sites for the Kitimat Terminal

NGP_B-FIGMAP-L Version: A



WorleyParsons resources & energy

REFERENCES
Initial Pipeline Route provided by WorleyParsons Calgary., LCC Projection (Central Meridian 120W, Standard Parallels 52N & 56N) and NAD 83 Datum.
National Parks & Indian Reserves: NRCan CLAB Lv1 (May 2009); AB Provincial Parks: TPR, AB Government (Sept. 2008); BC Provincial Parks: ILMB, BC Government (May 2009).
Hydrographic Data Source: Geography Division, Statistics Canada, 2006 Boundary Files, 92-160-XWE/F, Major Road and Rail data obtained from Geogratis © Department of Natural Resources Canada. All rights reserved.

SCALE	1:3,000,000
DATE	13 Aug 2009
FIGURE ID	11-026-003
REVISION	A
FIGURE NO.	D-3

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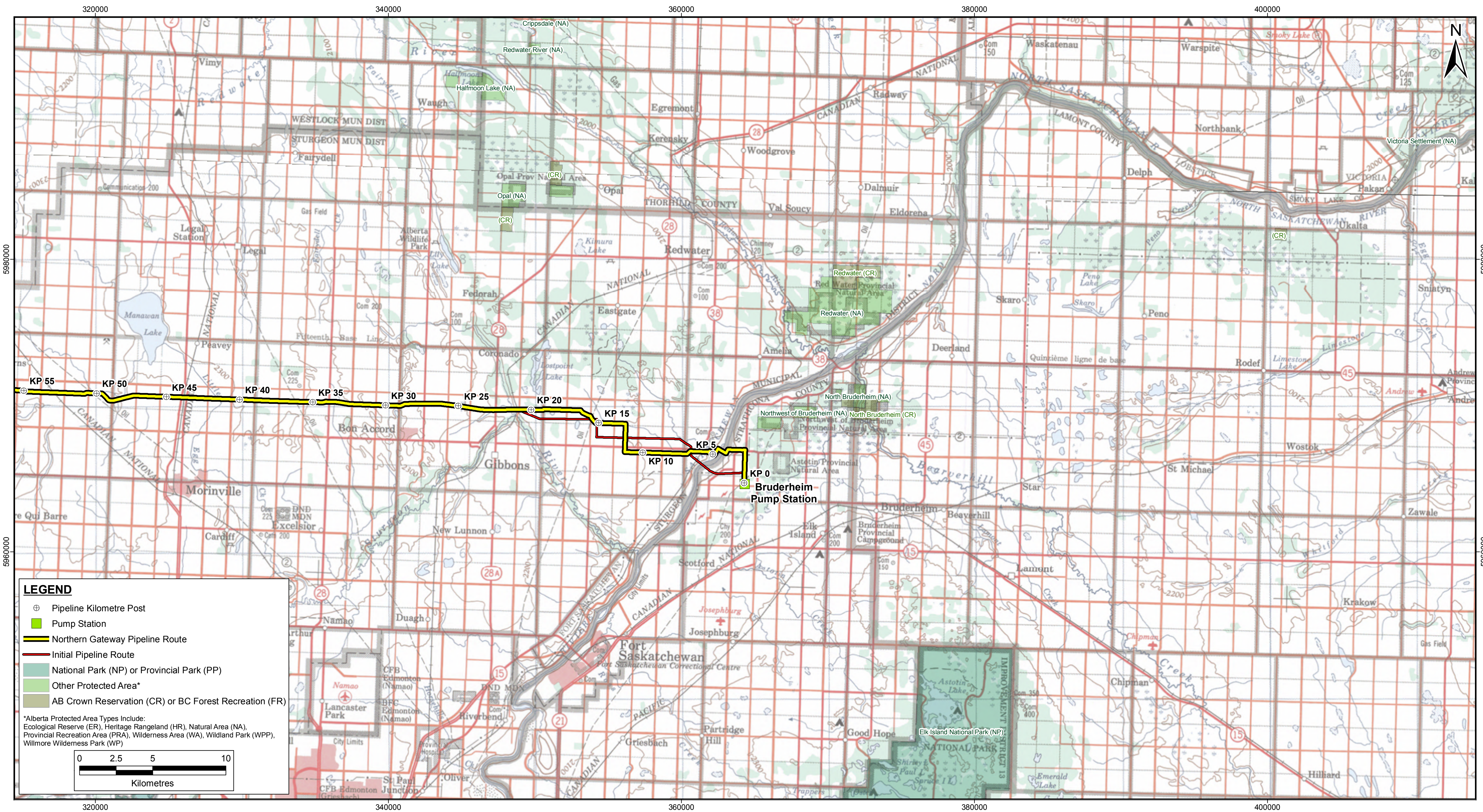
Initial Pipeline Route Alternatives

NGP_B-FIGMAP-L Version: A



WorleyParsons resources & energy	REFERENCES Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary., Initial Pipeline Route provided by WorleyParsons Calgary., UTM 12N Projection and NAD 83 Datum. National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009). © Topographic map reproduced under licence from Her Majesty the Queen in Right of Canada, with permission of Natural Resources Canada.
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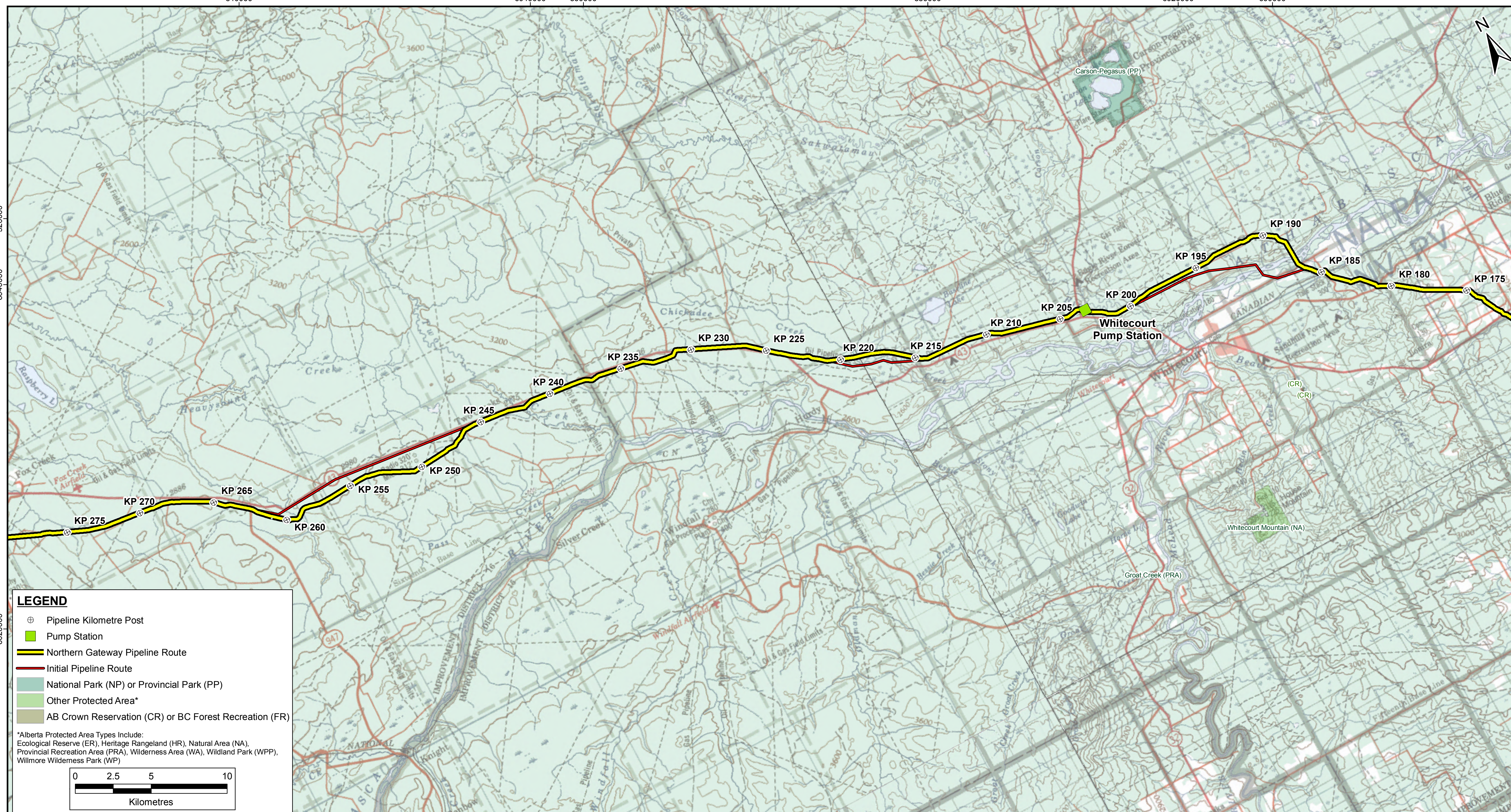
	Pipeline Route Revisions - Kilometre Posts 0 to 20

SCALE	1:250,000
DATE	19 Aug 2009
FIGURE ID	11-026-004
REVISION	A
FIGURE NO.	**D-4**

NGP_B-FIGMAP-L Version: A



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REFERENCES

Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary., Initial Pipeline Route provided by WorleyParsons Calgary., UTM 11N Projection and NAD 83 Datum.

National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE	1:250,000
DATE	19 Aug 2009
FIGURE ID	11-026-005
REVISION	A
FIGURE NO.	D-5

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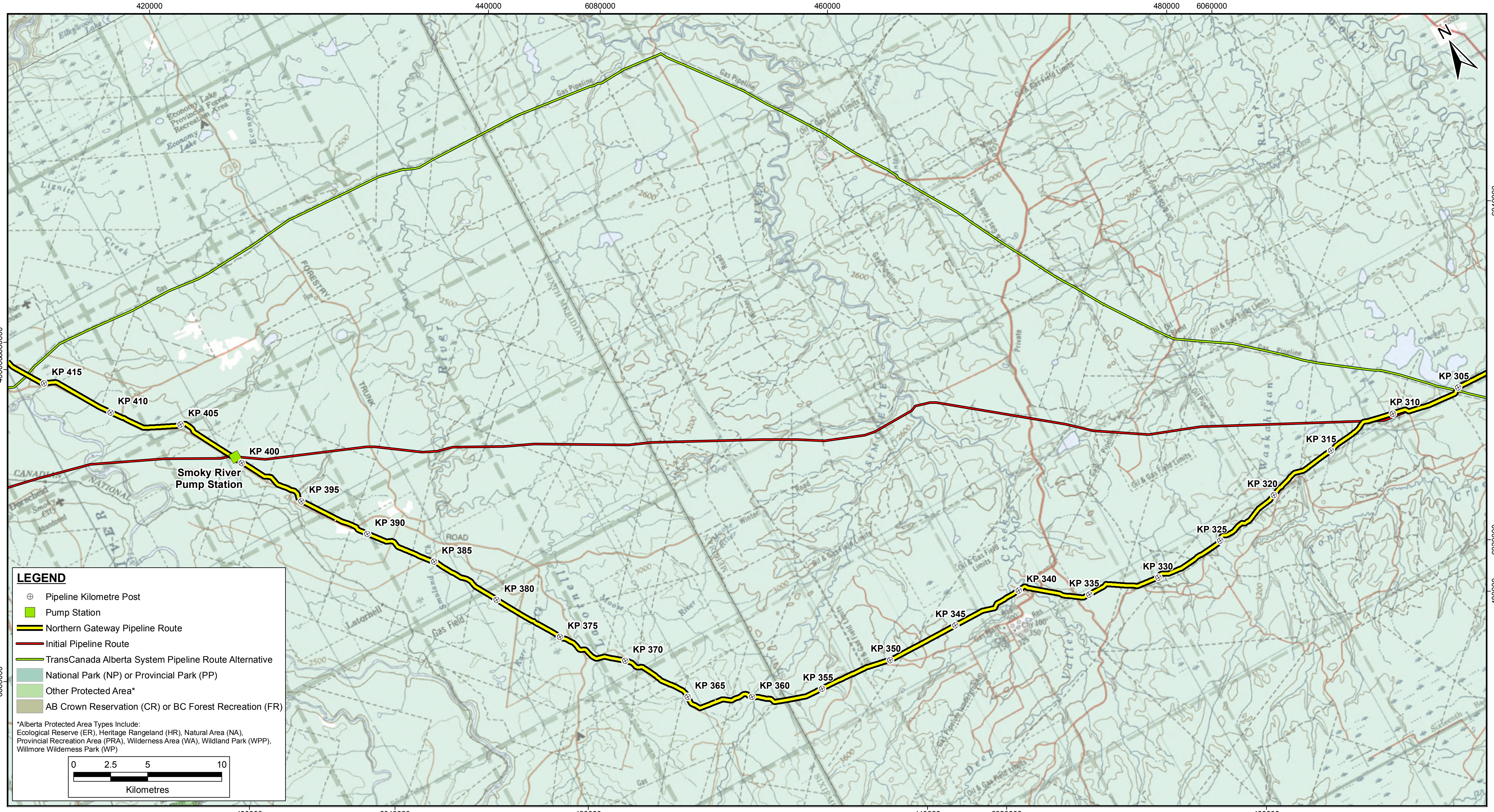
Pipeline Route Revisions - Kilometre Posts 186 to 260

NGP_B-FIGMAP-L Version: A



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REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary., Initial Pipeline Route provided by WorleyParsons Calgary., TransCanada Alberta System Pipeline Route Alternative provided by IHS Inc., Nov. 2008., UTM 11N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

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DATE 19 Aug 2009

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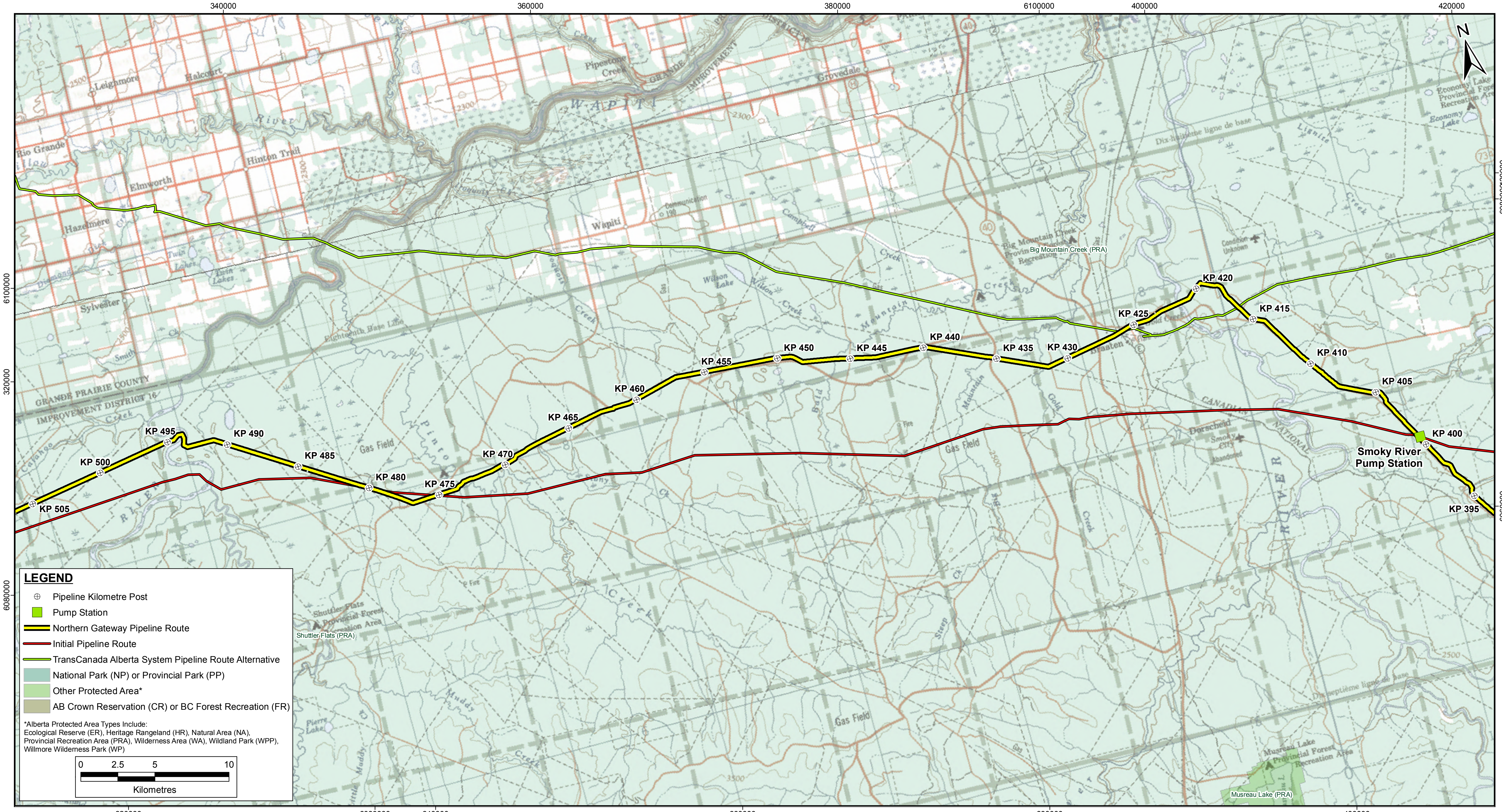
FIGURE ID 11-026-006
REVISION A
FIGURE NO.

Pipeline Route Revisions - Kilometre Posts 310 to 415

D-6

NGP_B-FIGMAP-L Version: A



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REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary., Initial Pipeline Route provided by WorleyParsons Calgary., TransCanada Alberta System Pipeline Route Alternative provided by IHS Inc., Nov. 2008., UTM 11N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE	1:250,000
DATE	19 Aug 2009
FIGURE ID	11-026-007
REVISION	A
FIGURE NO.	D-7

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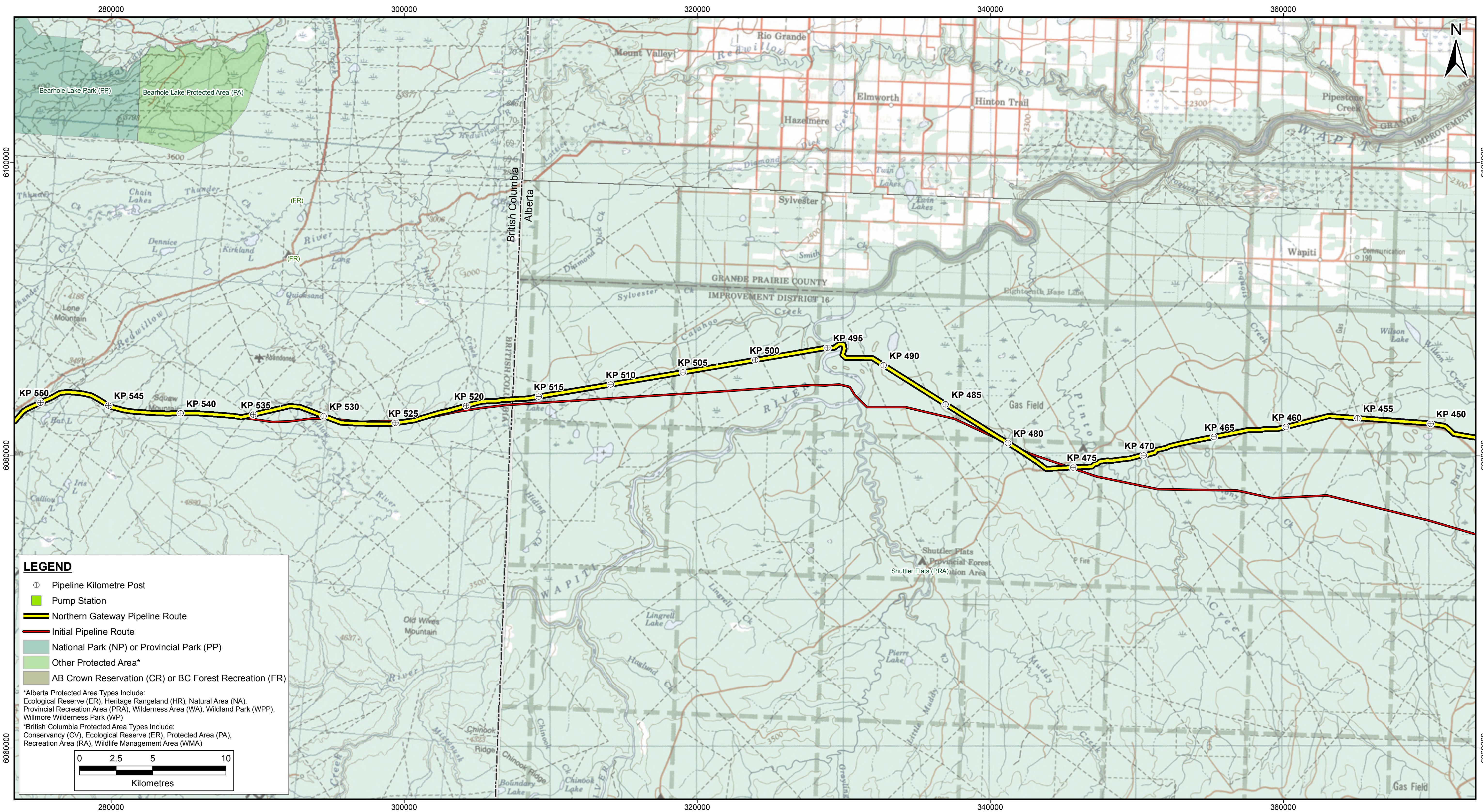
Pipeline Route Revisions - Kilometre Posts 415 to 475

NGP_B-FIGMAP-L Version: A



WorleyParsons resources & energy

REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary., Initial Pipeline Route provided by WorleyParsons Calgary., UTM 11N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE	1:250,000
DATE	19 Aug 2009
FIGURE ID	11-026-008
REVISION	A
FIGURE NO.	D-8

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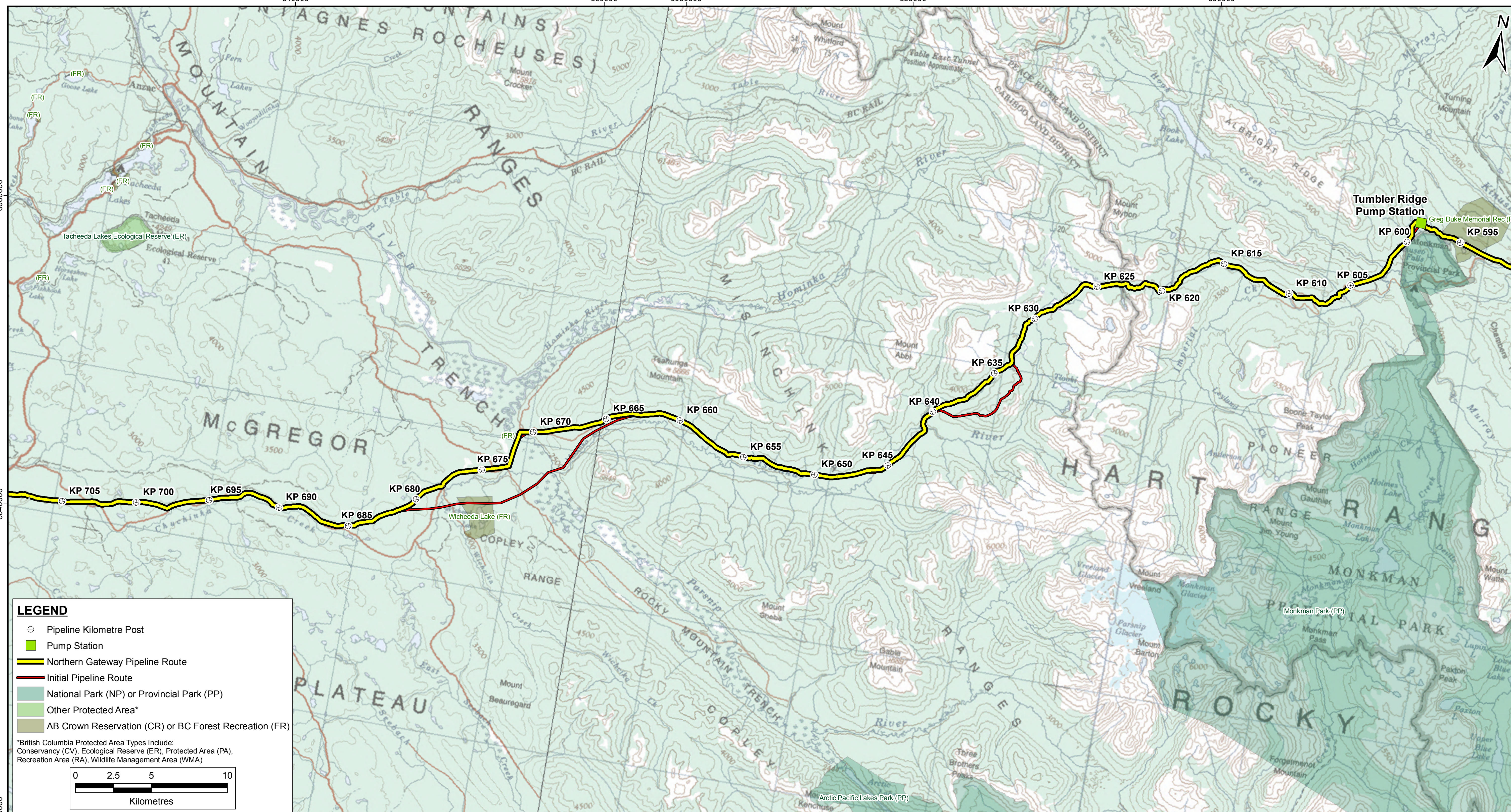
Pipeline Route Revisions - Kilometre Posts 475 to 535

NGP_B-FIGMAP-L Version: A



WorleyParsons resources & energy

REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary., Initial Pipeline Route provided by WorleyParsons Calgary., UTM 10N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE	1:250,000
DATE	19 Aug 2009
FIGURE ID	11-026-009
REVISION	A
FIGURE NO.	D-9

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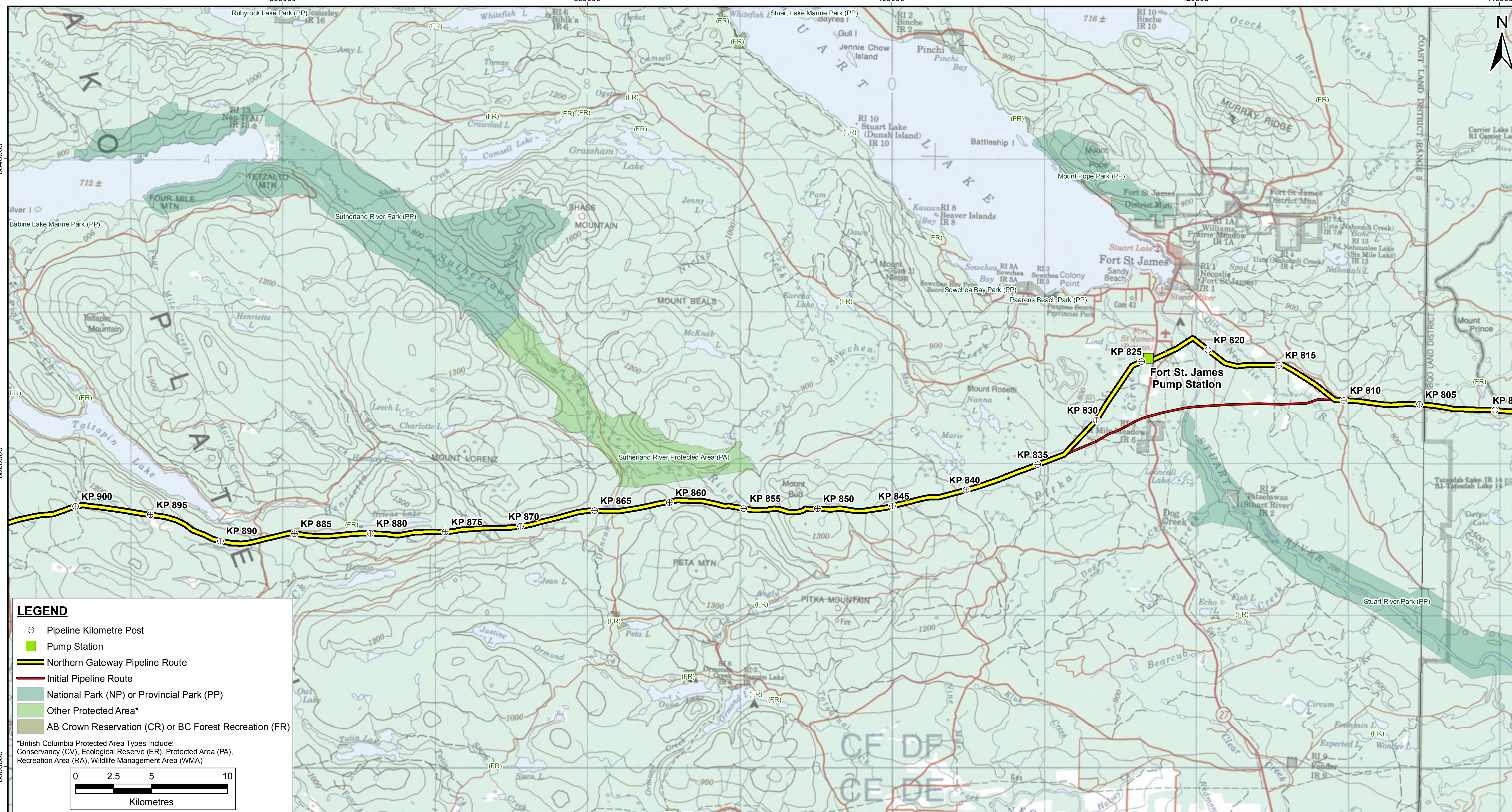
ENBRIDGE NORTHERN GATEWAY PROJECT

Pipeline Route Revisions - Kilometre Posts 634 to 681

NGP_B-FIGMAP-L Version: A



REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary., Initial Pipeline Route provided by WorleyParsons Calgary., UTM 10N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

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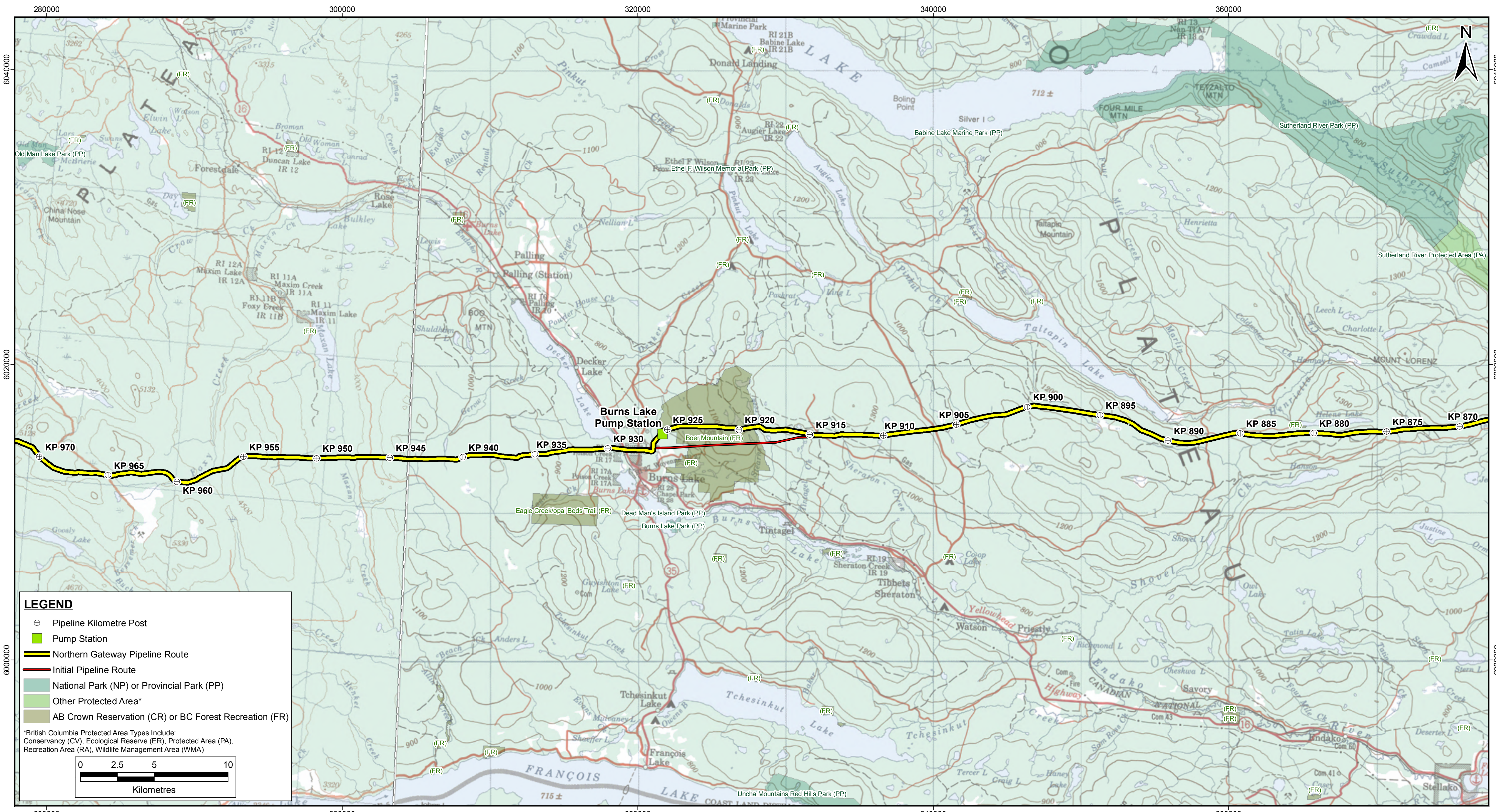
Pipeline Route Revisions - Kilometre Posts 810 to 833

SCALE	1:250,000
DATE	19 Aug 2009
FIGURE ID	11-026-010
REVISION	A
FIGURE NO.	D-10

NGP_B-FIGMAP-L Version: A



WorleyParsons resources & energy

REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary., Initial Pipeline Route provided by WorleyParsons Calgary., UTM 10N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE	1:250,000
DATE	19 Aug 2009
FIGURE ID	11-026-011
REVISION	A
FIGURE NO.	D-11

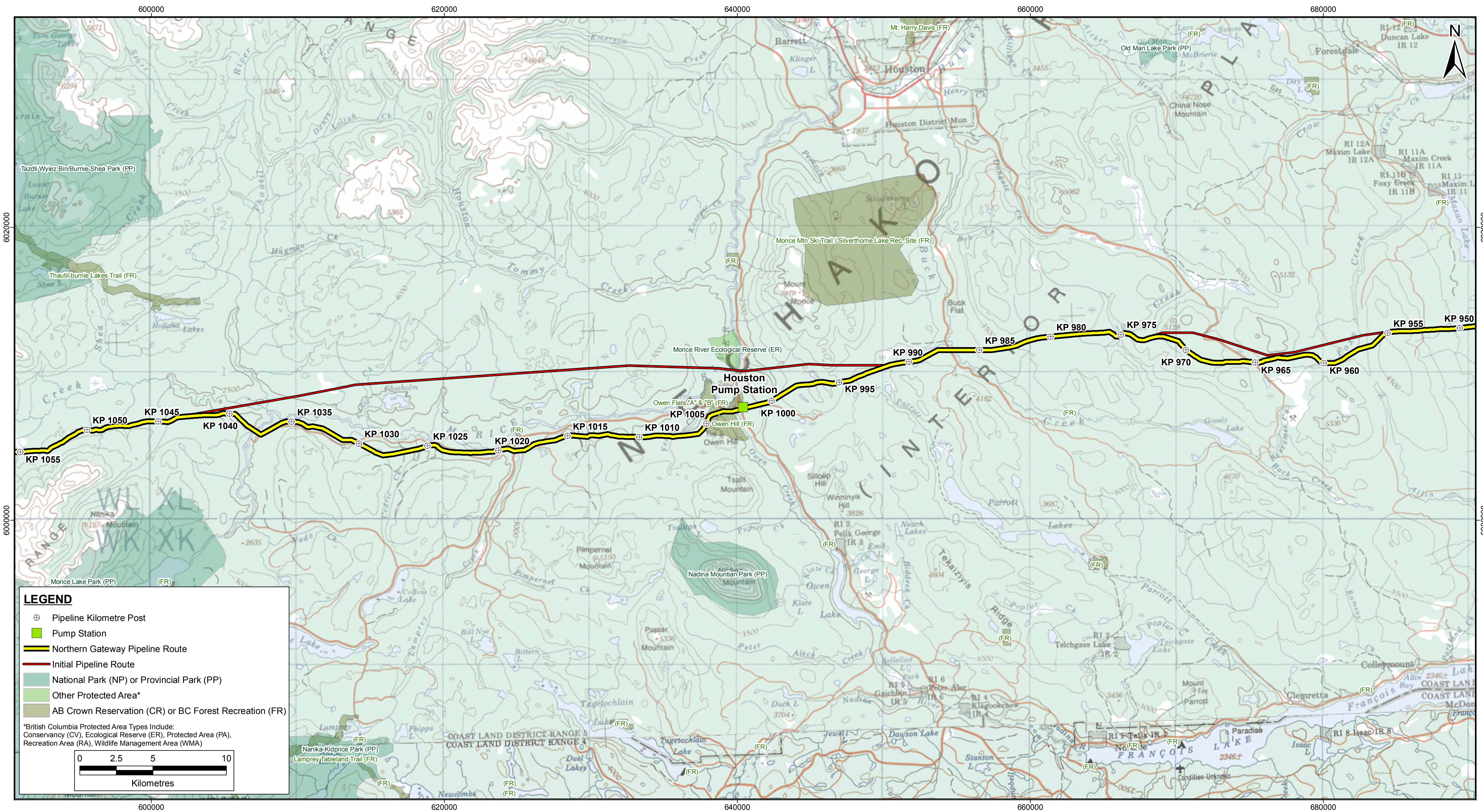
PREPARED FOR

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT

Pipeline Route Revisions - Kilometre Posts 915 to 927

NGP_B-FIGMAP-L Version: A



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resources & energy

REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary., Initial Pipeline Route provided by WorleyParsons Calgary., UTM 9N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE 1:250,000
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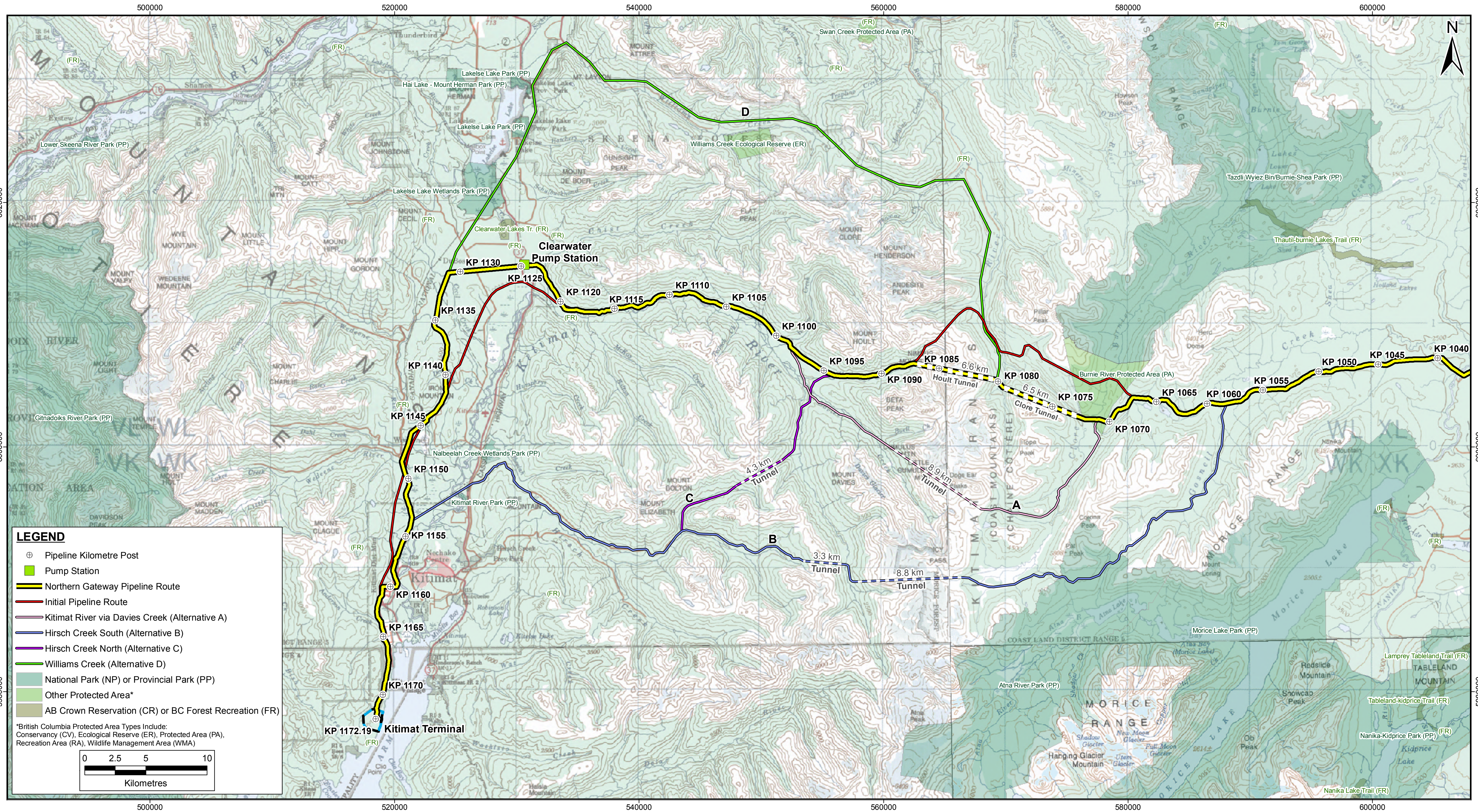
ENBRIDGE NORTHERN GATEWAY PROJECT

FIGURE ID 11-026-012
REVISION A

Pipeline Route Revisions - Kilometre Posts 955 to 1042

FIGURE NO.
D-12

NGP_B-FIGMAP-L Version: A



WorleyParsons
resources & energy

REFERENCES
Pipeline Route: Rev R, 2009 supplied by WorleyParsons Calgary., Initial Pipeline Route provided by WorleyParsons Calgary., Alternate routes, 2007 supplied by WorleyParsons Calgary., UTM 9N Projection and NAD 83 Datum.
National Parks: NRCan CLAB Lv1 (May 2009); AB Provincial Parks, Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Provincial Parks, Protected Areas, & Forest Recreation: ILMB, BC Government (May 2009).

SCALE	1:300,000
DATE	20 Aug 2009
FIGURE ID	11-026-013
REVISION	A
FIGURE NO.	D-13

PREPARED FOR

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT

Pipeline Route Revisions - Kilometre Posts 1067 to 1161

NGP_B-FIGMAP-L Version: A

Appendix E Supporting Geotechnical Reports

Report No.	Title
E-1	Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project, Bruderheim, Alberta to Kitimat, BC
E-1-1	Acid Rock Drainage and Metal Leaching Field Investigation, Enbridge Northern Gateway Project
E-1-2	Identification and Mitigation of Acid Rock Drainage and Metal Leaching During Construction, Enbridge Northern Gateway Project
E-2	Preliminary Geotechnical Report on Proposed Coast Mountain Tunnels Route Rev R KP 1072 to KP 1087), Enbridge Northern Gateway Project
E-3	Preliminary Geotechnical Proposed Kitimat Terminal Enbridge Northern Gateway Project Kitimat, British Columbia

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Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC

Submitted to:
Northern Gateway Pipelines Inc.
Calgary, Alberta

Submitted by:

AMEC Earth & Environmental,
a division of AMEC Americas Limited

Burnaby, BC

September 9, 2009

Revised March 26, 2010

AMEC File: EG0926008 3001
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IMPORTANT NOTICE

1.0 INTRODUCTION

1.1 Purpose

This report presents preliminary overall geotechnical evaluations and recommendations for the Enbridge Northern Gateway Project (the Project) from the Bruderheim Station, near Bruderheim, Alberta to the Kitimat Terminal, located near Kitimat, B.C. This report discusses overall geotechnical aspects of the proposed pipeline route based on the Revision R (Rev. R) pipeline route. The Rev R route is a corridor, nominally 1 km wide centered on the Rev. R alignment that is 1172 km long. Two parallel pipelines would be constructed: a 914 mm oil export pipeline flowing toward the west and a 508 mm condensate pipeline flowing toward the east. The pipelines will share a permanent right-of-way (RoW) that will normally be 25 m wide.

This report was prepared by AMEC Earth & Environmental (AMEC) at the request of Northern Gateway Pipelines Inc. in conjunction with their engineering consultant, WorleyParsons Calgary.

The pipeline route as it is presently constituted has evolved through various revisions during the routing studies that have been ongoing for several years. The presently considered Rev. R is shown in overview on Figure 1.1. Figures A-1 to A-11 in Appendix A show more details of the route. Further optimizations of the route may occur during ongoing design studies.

1.2 Project Overview

As currently proposed, the Enbridge Gateway Project will consist of the following:

1. A 914 mm OD (outside diameter) (NPS 36) oil pipeline from the Bruderheim Station to the Kitimat Terminal, a distance of approximately 1172 km.
2. A 508 mm OD (NPS 20) condensate pipeline, located in the same right-of-way (RoW) as the oil pipeline, from the Kitimat Terminal to the Bruderheim Station.
3. The Bruderheim Station, consisting of an oil initiating pump station and a condensate receiving station.
4. Intermediate pump stations at eight locations along the pipeline route.
5. Two tunnels, approximately 6.6 and 6.5 km long, located approximately 50 km northeast of Kitimat, to route the oil and condensate pipelines between the Clore River and Hoult Creek valleys. Geotechnical aspects of the tunnels are discussed under separate cover (AMEC 2009a).
6. Kitimat Terminal, located on the west side of Kitimat Arm. Geotechnical aspects of the terminal are discussed under separate cover (AMEC 2009b).

Additional facilities include pump stations, powerlines, camps, equipment stockpile areas and other infrastructure. Preliminary geotechnical input has been provided to the project team on these facilities; however, these portions of the infrastructure are not discussed in this report.

The evaluation and recommendations presented in this report are based on the following information:

1. Review of available mapping and published materials. References to key published information are provided in Table B-1 and elsewhere in the report.
2. Previous experience in the areas under discussion.
3. Review of LiDAR data including hillshade images generated by WorleyParsons Calgary and AMEC Earth & Environmental (AMEC) for some crossings and slopes. LiDAR base data is not yet available for all crossings.
4. Helicopter reconnaissances of the pipeline route were carried out by AMEC, Enbridge and WorleyParsons Calgary personnel at various times between 2003 and December 2009.
5. Site specific ground reconnaissances have been carried out at selected locations along the route, particularly at selected water course crossings and adjacent approach slopes. However, not all slopes and stream crossings had been reconnoitred on the ground at the time of writing. The field reconnaissances were usually made in the company of representatives from Enbridge and other members of the project team.
6. Drilling has been carried out at a few of the key water course crossings and on adjacent approach slopes. Geophysics has not yet been carried out on any of the water course crossings or approach slopes.

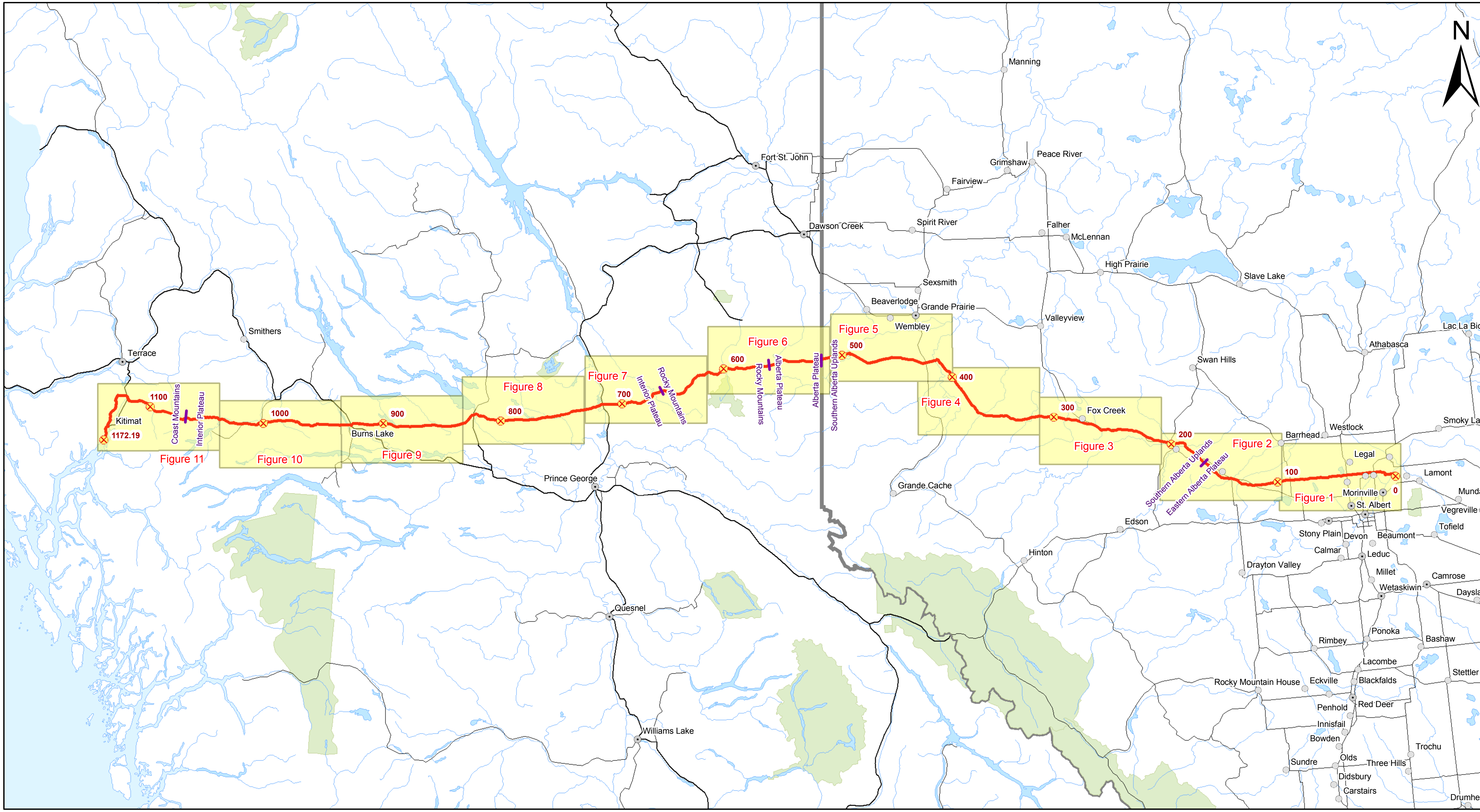
Comprehensive geotechnical studies will be carried out during detailed design.

1.3 Organization

This report is organized as follows:

1. Table B-1 (Appendix B) provides a summary geotechnical description and preliminary mitigative recommendations on a kilometer by kilometer basis for the Rev R pipeline route.
2. Discussion of topography and physiographic regions, bedrock geology, surficial geology and stability relative to geotechnical aspects of the route appears in Section 2.
3. Discussion of selected geotechnical aspects and issues with respect to the proposed route appears in Section 3.
4. Natural terrain hazards and risk analyses are discussed in Section 4
5. Preliminary geotechnical mitigative recommendations are discussed in Section 5 and in Table B-1.

The units used in this report are primarily metric except that both the systems are used in some cases where the source measurements were Imperial units.



ENBRIDGE NORTHERN GATEWAY PIPELINES

LEGEND

- City
- Town
- Road
- River
- Lake
- Park
- Kilometre Post (July 27, 2009)
- Proposed Route (July 27, 2009)
- Physiographic Boundary
- Figure Index

SCALE: 1:3,000,000

0 25 50 75
Kilometers

PROJECTION: LCC
DATUM: NAD 83

ENBRIDGE NORTHERN GATEWAY PROJECT

General Location Plan & Physiographic Boundaries

PROJECT NUMBER: EG0926008.3001

DATE: February 5, 2010

QA/QC: DC

REFERENCE: **Pipeline Route: Rev R, July 27, 2009**

CONTRACTOR: AMEC Earth & Environmental

Figure 1.1

Y:\GIS\Projects\CE\CE03210_GatewayMapping\MXD\NEB-application\NEB_route_overview_v2.mxd

2.0 SETTING

2.1 General

The proposed pipeline route runs generally toward the west from near Bruderheim, northeast of Edmonton. Elevations along the proposed pipeline route range from 600 m (1975 ft) near Bruderheim, rising across Alberta to near 1200 m (3900 ft) in the foothills and to 1430 m (4700 ft) through a pass in the Rocky Mountains southwest of Tumbler Ridge. The Continental Divide (the point at which the surface water drainage divides between streams ultimately flowing toward the Arctic and Pacific Oceans) is crossed at about KP 730 west of the Rocky Mountains at an elevation of about 3600 ft (1100 m). Elevations west of the divide are typically under about 915 m (3000 ft) with the exception the Coast Mountains. The route crosses the Coastal Mountains in two proposed tunnels at approximate elevations of 915 to 760 m (3000 ft to 2500 ft) and descends to near sea level near Kitimat. Elevations at the proposed terminal on the west side of Kitimat Arm are approximately 200 m or below. Except in central Alberta, parts of the Rockies and a few other areas, the stream valleys tend to be oriented near north-south. Thus, many parts of the route cross local ridges and streams, rather than being parallel to them.

The proposed pipeline route crosses six broad physiographic regions as defined in Alberta by Pettapiece (1986) and in British Columbia by Demarchi (1995). The physiographic regions used in this report are based on those used by the Project GEM environmental team. It should be further noted that the boundaries are approximate and that some overlap in terms of terrain characteristics near the boundaries between different areas. The physiographic regions form a convenient framework for general discussion of the topography, geology and natural terrain hazards. Descriptions of the regions appear below and the locations of the various physiographic regions are shown on Figure 1.1 and Figures A-1 to A-11 in Appendix A.

2.2 Eastern Alberta Plains

2.2.1 Topography and Physiography

The Eastern Alberta Plains (Eastern Alberta Plateau in some literature and materials) physiographic region extends from approximately KP 0 to approximately KP 165.8. The topography is typically flat to rolling with incised stream valleys that vary up to several tens of meters deep. Major streams in this area include the North Saskatchewan, Pembina and Paddle Rivers. Upland elevations along the proposed pipeline route rise from 700 m (2300 ft) to approximately 800 m (2600 ft) toward the west. The area is underlain by sedimentary bedrock with little structure other than the generally flat-lying bedrock units.

The Eastern Alberta Plains physiographic region has a continental climate, consisting of short warm summers and long cold winters, typically with continuous winter snow cover. Most precipitation falls as rain during the summer months (Bowser et al. 1962; Lindsay et al. 1968). The mean annual temperature is about 1.5°C (varying with elevation and location), with mean annual precipitation in the range of 400-500 mm.

2.2.2 Surficial Geology

Terrain within the Eastern Alberta Plains is typically undulating and is underlain by fine textured glaciolacustrine deposits (silts and clays with some interbedded sand) and undulating to hummocky moraine consisting of calcareous fine textured till (typically silty clay to clayey silt with varying sand to boulder contents). Localized coarse glaciofluvial deposits (sand and gravel containing varying contents of pebbles to boulders) also occur, typically along valleys that carried glacial meltwater flows at the end of the last glaciation around 9,500 to 11,000 years BP (before present). Large areas are underlain by glacial lake deposits including Glacial Lake Edmonton. Numerous other smaller glacial lakes were also present and these areas are also underlain by glaciolacustrine clays. Aeolian deposits cover wide areas to variable depths and represent a reworking of the glaciolacustrine deposits by wind near the end of glaciation.

Recent accumulations of coarse textured alluvial deposits occur along water courses. Organic deposits in the form of peat (muskeg) occur along many of the flat bottomed outwash channels or valleys and in terrain depressions. Recent lacustrine accumulations of silt and clay also occur.

The deposition and erosion that occurred during the Late Wisconsinan Glaciation was a major influence on the geomorphology of the Eastern Alberta Plains. During this glaciation, the region was overrun by the Laurentide Ice Sheet (from the Canadian Shield) up to approximately 13,000 years before present (BP) (Dyke and Prest 1987a). Deglaciation occurred via stagnation and down-wasting. The ice margin retreated to the northeast due to thinning of the ice sheet.

During deglaciation, large proglacial lakes formed in areas bounded between uplands and the retreating ice. The area between Bruderheim and approximately north of Morinville (KP 0 to 44) is underlain in part by glaciolacustrine sediments from Glacial Lake Edmonton that include medium to high plastic clays and silty clays, layers of silt and some sand interbeds. Varved sediments are also present. These deposits are up to 80 m thick and form a flat to gentle topography (Shetson 1990). In higher areas, glacial till occurs as either ground moraine or stagnation moraine. Aeolian sands and sand dunes are present where the glaciolacustrine deposits have been reworked by wind.

The area from Morinville to the Pembina River (KP 131) is underlain by fine to medium textured stagnation moraine (glacial till) of varying thicknesses. Localized inclusions of water sorted material are common and Holocene (interglacial time period that started at the end of the last ice age) organic, fluvial, and lacustrine accumulations occur in depressions and along river valleys (Shetson 1990). The surface form is generally undulating to hummocky.

The area from Pembina River to KP 201 near Whitecourt (beyond the end of the physiographic region) is dominated by ice contact glaciolacustrine deposition. Sediments vary in texture but are commonly medium to fine textured and extend to depths of approximately 20 metres (Shetson 1990). Glacial till including ice rafted material is exposed in some areas within this widespread glaciolacustrine deposit. Short segments of the pipeline route traverse ground moraine and stagnation moraine. Eolian deposits are found adjacent to the Athabasca River

valley, and the accumulation of Holocene fluvial and organic sediments occurs along modern rivers and in depressional areas, respectively.

2.2.3 Bedrock Geology

The Eastern Alberta Plains Physiographic Region is underlain by bedrock of the Horseshoe Canyon and Scollard Formations (Journeay et al 2000a). The bedrock formations in this region are flat lying and generally have not been folded by past tectonic activity. The Upper Cretaceous Horseshoe Canyon Formation underlies the majority of this physiographic region and includes sandstone, mudstone, and shale. Localized ironstone concretions and scattered coal seams may also be present (Shetson 1990). The Horseshoe Canyon Formation contains some bentonitic seams, but is generally less subject to slope stability concerns than the underlying Scollard Formation.

The Scollard Formation is Tertiary to Cretaceous in age and contains sandstone and mudstone with frequent interbeds of shale and coal (Journeay et al 2000a). The formation mainly occurs near and beyond the west end of the Eastern Alberta Plains Physiographic Region. The Scollard Formation contains bentonite and related smectite clays, resulting in low shear strengths in some of the beds. As a result, the Scollard Formation is a regional control on bedrock slope stability where it is located close to the ground surface.

2.3 Southern Alberta Uplands

2.3.1 Topography and Physiography

The Southern Alberta Uplands physiographic region extends from approximately KP 165.8 to KP 516.8 at the BC-Alberta boundary. The upland terrain is generally rolling to ridged with local areas that are rougher and dissected including south of the Athabasca River. Local topography is generally controlled by deep surficial deposits with an undulating to hummocky surface. High bedrock controlled relief occurs along the foothills of the Rocky Mountains at the west edge of the area. The area is underlain by sedimentary bedrock that is close to flat lying with some regional folding or warping in some areas. Elevations along the proposed route are more variable than to the east, but typically range from 800 to 975 m (2600 to 3200 ft) in the upland areas. Major streams in this area include the Athabasca, Sakwatamau, Iosegun, Little Smoky, Latornell, Smoky, Simonette and Wapiti Rivers, which flow in valleys up to 150 m deep with slopes that are very steep in some areas. Some of the named “creeks” such as Deep Valley Creek also have valleys with depths similar to the river valleys previously listed, although in some cases the valleys may be narrower and with steeper sideslopes than the main river valleys.

The climate of the Southern Alberta Uplands is continental and is characterized by cold winters and short cool summers (Ecological Stratification Working Group 1996). The mean annual temperature ranges between 1 and 2°C, mean summer temperatures range between 13 and 14°C, and mean winter temperatures range from -9 to -13°C. The mean annual precipitation ranges between 450 and 600 mm, falling mostly as rain in the summer months (Ecological Stratification Working Group 1996).

2.3.2 Surficial Geology

Surficial materials include undulating to hummocky till plains, glaciolacustrine plains, and localized glaciofluvial outwash and deltaic sediments. Local aeolian deposits occur in some areas where the fine textured glaciofluvial and glaciolacustrine deposits were reworked by the wind, possibly soon after the end of glaciation prior to the establishment of ground cover vegetation. Coarse textured fluvial accumulations occur along modern rivers and organic and lacustrine deposits occur in low areas (Twardy and Corns 1980; Knapik and Lindsay 1983). Preglacial valleys have been infilled in some areas with sediments including bouldery materials, preglacial glaciofluvial materials and glacial sediments and till. These valley infill deposits may be a major consideration for directional drilling.

The geomorphology and surficial sediments and deposits of the Southern Alberta Uplands are similar to those of the Eastern Alberta Plains which were also overrun by the Laurentide Ice Sheet. The till in the Southern Alberta Uplands was deposited by the continental glaciation and is generally characterized by a sandy clay matrix with low coarse fragment contents (Fenton and Pawlowicz 2002). Topographically, the till is typically undulating to hummocky in lower elevation areas and increases in relief along the western margins of the region within the foothills of the Rocky Mountains.

Large proglacial lakes formed in this area during deglaciation (Dyke and Prest 1987a; Fenton and Pawlowicz 2002). Gentle to flat topography is associated with the glaciolacustrine deposits which are generally greater than 20 metres thick (Twardy and Corns 1980; Knapik and Lindsay 1983). The sediments are generally medium to high plastic clay with low coarse fragment content.

Moderate to coarse textured glaciofluvial sediments occur in many of the river valleys. These sediments are characterized by localized planar terraces with steep terrace fronts, resulting from the subsequent down cutting of the modern rivers (Fenton and Pawlowicz 2002).

Longitudinal and parabolic dunes formed on the underlying glaciolacustrine and glacial till surfaces in some areas. Many of these features formed soon after glaciation and are either relatively inactive or not presently active. These features tend to have a moderate relief of approximately 5 to 10 metres and are composed of sand and silt.

Thick organic deposits occur in many of the lower areas in this region. These deposits may be relatively thick (locally up to 3 m or more) occupying areas once containing Holocene lakes.

2.3.3 Bedrock Geology

The Southern Alberta Uplands physiographic region is underlain by the Upper Paskapoo, Wapiti and Scollard Formations (Journeay et al 2000a; Knapik and Lindsay 1983). The rock strata in the eastern portion of this region are generally flat lying while thrust faults parallel to the overall trends of the Rocky Mountains occur along the western margin (Journeay et al 2000a). Due to

regional warping and the terrain elevations, the bedrock formations encountered along the route repeat across the Southern Alberta Uplands. The Upper Wapiti and laterally equivalent Horseshoe Canyon Formations occur near and east of the eastern boundary and also in the northwestern part of the region. The Scollard Formation forms a curved outcrop pattern that is crossed by the pipeline route west of the Athabasca River and also near the Latornell River. The broad central area of the region (as far as the pipeline route is concerned) is underlain by the Upper Paskapoo Formation.

Similar to the Eastern Alberta Plains, the Tertiary to Cretaceous Scollard Formation contains sandstone and mudstone, with frequent interbeds of shale and coal and some bentonite (Journeay et al 2000a). The Scollard Formation occurs near the eastern end of the region (Sakwatamau River, KP 200) and is again crossed near the Latornell River (KP 371.9). The Smoky River crossing is within the Wapiti Formation north of the Scollard Formation subcrop. Where the Scollard Formation outcrops, it tends to be a regional control on stability conditions due to the weak clay layers in the formation.

The Palaeocene Upper Paskapoo Formation contains cross-bedded sandstone with interbedded sandstone, siltstone and mudstone. Lenticular or laterally discontinuous strata often occur. Local shale and coal are present. In general, the Upper Paskapoo tends to have better stability conditions than the Scollard Formation, although slope stability concerns including slides can occur along the coal seams and some related clays. The Upper Paskapoo underlies the area from west of the Sakwatamau River (KP 200) to the Simonette River (KP 359.9).

The Late Cretaceous Upper Wapiti Formation is composed of non-marine cross-bedded sandstone with scattered conglomerate, siltstone and mudstone. Local coal seams occur within the formation (Journeay et al 2000a; Twardy and Corns 1980). Although most of the Upper Wapiti is mapped as non-marine, continuous seams of apparent bentonite or other high plastic clays have been found during previous AMEC work and widespread large deep-seated slope failures occur in the formation, particularly toward the northwest part of the route such as near the Wapiti River.

Evidence of “ice-rafted” bedrock was found during drilling investigations north of the Athabasca River near KP 188 near the eastern end of the Southern Alberta Uplands. In this area, an upper layer of predominantly sandstone bedrock is underlain by a gravel layer which is in turn underlain by a sedimentary sequence including sandstone that differs from the shallower bedrock. The ice-rafted bedrock is likely a result of a layer of bedrock moved laterally by a glacier and has implications with respect to directional drilling.

2.4 Alberta Plateau

2.4.1 Topography and Physiography

The Alberta Plateau Physiographic Region extends from approximately KP 516.8 to KP 560.4 and is the BC equivalent of the Southern Alberta Uplands. There are no major streams in this area; Redwillow Creek is one of the larger creeks. The area is gently rolling with some steeper ridges. Typical elevations along the proposed pipeline route range from 1070 to 1225 m (3500 to 4000 ft). The eastern-most thrust faults associated with the Rocky Mountains occur in this area and the bedding dips vary from gently dipping to steeply dipping where local folds or thrust faults occur.

The climate of the Alberta Plateau is continental and is characterized by cold winters and short cool summers (Ecological Stratification Working Group, 1996). The mean annual temperature ranges between 1 and 2°C, mean summer temperatures range between 13 and 14°C, and mean winter temperatures range from -9 to -13°C depending on elevation and location. The mean annual precipitation ranges between 450 and 600 mm, falling mostly as rain in the summer months (Ecological Stratification Working Group 1996).

2.4.2 Surficial Geology

Surface materials, surface expression and drainage conditions are similar to the Southern Alberta Uplands discussed above. This region has been significantly influenced by the bedrock topography of the foothills of the Rocky Mountains. Vold et al. (1977) identified six primary surficial materials including glacial till, glaciolacustrine, colluvial (deposits that have moved or been placed under the influence of gravity), glaciofluvial and organic deposits. As with the Southern Alberta Uplands to the east, the glacial till and glaciolacustrine deposits tend to be clayey and frequently contain medium to high plastic clays. The glaciofluvial deposits occur as valley fills and terraces along valleys that have carried meltwater flows and in some areas as deltas into glacial lakes.

Preglacial valleys have been infilled in some areas with glaciofluvial sediments with variable boulder content, glaciolacustrine sediments and till. These valley fill deposits may be a major consideration for directional drilling.

In general, tills of variable thickness overlie the bedrock topography that is higher relief than to the east (Fenton and Pawlowicz 2002). Based on clast lithologies within the till, glacial ice from three separate sources were present in the general area. The sources include the continental Laurentide and Cordilleran ice sheets and local montane ice from the Rocky Mountains. The relationships between the various ice lobes and the flow directions of the two continental glaciers are poorly understood (Fenton and Pawlowicz 2002). As a result of glacial scour, bedrock is exposed in local areas.

The lowland areas include extensive deposits of both glaciofluvial and Holocene fluvial materials. Broad glaciofluvial outwash plains were deposited along river valleys. This glacial sediment is generally coarse textured with a high content of coarse fragments. Glaciofluvial and alluvial fans, some of which are still subject to active erosion and deposition, are crossed by the proposed pipeline route in some areas. The topography of these deposits is typically gentle to flat, except where modern river valleys have cut down through the deposits. Fine textured fluvial sediments on low relief topography are also found along the margins of modern rivers. Thick organics (muskeg) occur in low areas, some in the former sites of Holocene lakes.

2.4.3 Bedrock Geology

The bedrock underlying the Alberta Plateau physiographic region is Triassic to Cretaceous in age and primarily consists of the Spray River, Brazeau, and Smokey Assemblages. Several thrust faults occur (Journeay et al 2000a; Journeay et al 2000b). The Triassic to Jurassic Spray River assemblage and contains continental margin siltstone, sandstone, and limestone. The Upper Cretaceous Smoky Group contains fordeep marine shale with siltstone and sandstone. The Brazeau Group is also Upper Cretaceous in age and consists of fordeep marine clastic wedge materials with eastward prograding sandstone, conglomerate, and shale (Journeay et al 2000b). Typically, these formations contain less high plastic clay than many of the rock types to the east and, as a result, bedrock stability conditions tend to be more favourable.

2.5 Rocky Mountains

2.5.1 Topography and Physiography

The Rocky Mountains Physiographic Region extends from approximately KP 560.4 to KP 663.5. The topography is primarily bedrock controlled and exhibits high relief with steep slope gradients. Regional elevations are significantly higher than in the surrounding physiographic regions, reaching almost 1500 m along the proposed pipeline route.

Much of the topography is controlled by the underlying folded and thrust faulted sedimentary rocks which form major ridges oriented northwest to southeast. Parts of the route parallel valleys that cut across the major mountain ridges including Kinuseo Creek, Imperial Creek and the Missinka River valleys. Major river crossings include the Murray (KP 598.6) and Missinka River (main crossings at KP 641.3 and 646.2). Elevations along the proposed pipeline route range from 1070 m (3500 ft) at the east end to 915 m (3000 ft) at the Murray River to 1460 m (4800 ft) at the crossing of the Rocky Mountains at an unnamed pass. At the west end of the Rocky Mountains Region, elevations of 760 m (2500 ft) occur at the west end of the Missinka Valley.

The underlying rock types range from folded sandstone to mudstone (shale) sedimentary rocks in the east to older stronger rocks including limestone and quartzite as well as rocks containing chert in the west. The folds and thrust faulting are strong controls on the local topography.

The regional climate is influenced by the Rocky Mountains and varies in a west to east direction as well as by altitude. The mean annual temperature for the area is approximately 1.5°C with a summer mean of 12°C and a winter mean of -10°C. Mean annual precipitation ranges from 500 to 700 mm with the highest values occurring in the south and on the west side of the mountains. On the east side of the mountains, winter temperatures tend to be cooler due to the cold air pooling against the mountains, although Chinooks occur east of the mountains and in the foothills area to the east. At higher elevations, snowfall comprises half the annual precipitation.

2.5.2 Surficial Geology

The Cordilleran Ice Sheet covered most the Rocky Mountains during the last glacial maximum. The coalescing of valley glaciers and ice sheets produced a significant dome which drained eastward to meet the Laurentide Ice Sheet along the foothills in Alberta (Fenton and Pawlowicz 2002). Toward the end of glaciation, the large ice dome was replaced by valley glaciers that actively modified the landscape through localized erosion and deposition. Within the Rocky Mountains, the proposed route in part follows river drainages that were occupied by main trunk glaciers and tributary side valley glaciers. The Rock Mountains Region generally has high relief with steep U-shaped valley sidewalls, except where controlled by bedrock geology or where subsequent erosion has occurred. Along the valley bottoms, the topography is undulating to hummocky, depending on the presence of bedrock control.

Glacial till, colluvium, and exposed bedrock are predominant overall (Vold et al. 1977). Where the pipeline route runs parallel to valleys through the Rockies, deposits along these valleys typically include glaciofluvial terraces, minor glaciolacustrine materials, alluvial fans and organic deposits with areas of intervening rock ridges, shallow rock and shallow glacial till. Shallow organic deposits occur in some of the upland areas, in part due to the prevailing climatic conditions and perched shallow groundwater.

Frost processes such as solifluction and nivation occur at high altitudes in local areas. Recent work has suggested that some of these areas may be less thermally active than in the past as a result of a general warming trend (the recent peak of glacial extent was in the “Little Ice Age” in the mid to late 1700’s).

The majority of this physiographic region has undergone significant erosion, resulting in a predominantly bedrock controlled environment with exposed bedrock occurring throughout the area. Glacial till and colluvium occur throughout the region. Parent material textures are variable; however, as they are directly related to the local bedrock lithology and the glacial transport distance. Generally the till in this region is medium to coarse textured, similar to the colluvial deposits (i.e., sand to cobbles and boulders with variable silt content). Coarse fragment contents are variable but are generally moderate to high.

Glaciofluvial and glaciolacustrine terraces and plains also occur along sections of the proposed route. The glaciofluvial sediments are generally coarse textured and high in coarse fragment content. Glaciolacustrine sediments are typically gently undulating, silty and have a low coarse fragment content except where interbedded with other materials.

Modern alluvial deposition occurs along the river valleys. Organic accumulations occur at all elevations within this physiographic region and are controlled by local surface and groundwater conditions. As a result, the organics are not confined to depressed areas, but also occur on widespread areas of sloping ground at high altitude. The depths of the organics vary from less than 1 m to locally much deeper, depending in part on the underlying bedrock or till topography.

Permafrost may be present in very limited areas at higher elevations; however, recent work by AMEC in similar areas has generally found that the permafrost that was previously present has thawed.

2.5.3 Bedrock Geology

Seven tectonic assemblages have been identified within the Rocky Mountains (Wheeler et al 1991). Widespread folding and faulting has produced aligned ridges that have been dissected into alpine and valley terrain.

The bedrock formations include the Windermere, Gog, Rocky Mountains, Kootenay, Besa River, Smokey, and Rundle Groups (Journeay et al 2000b), although not all of these groups underlie the proposed route. The Windermere Group is Palaeocene in age and contains clastic continental margin sediments with sandstone, siltstone, and shale. The Gog Group is Proterozoic to Cambrian in age and contains rifted continental margin sediments including shallow water quartzite, conglomerates, and mafic flows (Journeay et al 2000b). The Rocky Mountain group is Cambrian to Devonian in age and contains passive continental margin dolomite, limestone, sandstone, and shale. The Rundle Group is Devonian to Carboniferous in age with continental shelf carbonates and shale. The Kootenay Group is Jurassic to Cretaceous in age and comprises (marine) fordeep clastic wedges of marine sandstone and mudstone. The Smokey Group is Upper Cretaceous in age and contains fordeep marine shale, siltstones, and sandstones. The Besa River Group is Devonian to Mississippian in age and is comprised of marine shale, mudstone, and shale (Journeay et al 2000b).

Of note in the Rocky Mountains is that the rock types are typically much harder and stronger than the sedimentary rocks to the east. Strong rock types including sandstone and limestone are widespread. Extremely strong and tough quartzite and chert occur in several of the formations and rock groups. Excavation of these rock types will likely require drill and blast techniques.

The bedrock stability of most of the rock groups is reasonably good; however, the marine shales in the Smoky Group include some high plastic clay content and some large slides have occurred in areas underlain by this group.

Local widely scattered occurrences of Potentially Acid Generating (PAG) rocks may occur in the Rock Mountains. Acid Rock Drainage (ARD) considerations are discussed in AMEC (2009c and 2009d).

2.6 Interior Plateau

2.6.1 Topography and Physiography

The Interior Plateau Physiographic Region in BC extends from approximately KP 663.5 to KP 1066.9 and occupies a wide area of eastern and central BC. This physiographic region covers plateaus and plains of north-central British Columbia and the interior foothills of the Coast Mountains. The region includes the southern portion of the Northern Rocky Mountain Trench, the western flank of the McGregor Plateau, the northern portion of the Nechako Plateau, the Nechako Lowlands, and the Chilcotin Ranges in the west. The Rocky Mountain Trench was included in the east part of the area for the purposes of discussion in environmental reports and this usage is followed in the present report for uniformity.

The terrain is rolling to variably ridged. Some of the stream valleys are deeply incised, but many are wide with gentle to moderate slopes. Wide areas are underlain by drumlins (elongate ridges) that may be composed of glacial till or rock (technically roche moutonnee). Ridges with till cores are more frequent than ridges with rock cores. Elevations along the pipeline route range from 760 m (2500 ft) in the east and west and reach 1075 m (3500 ft) in parts of the center of the area. Major streams include the Parsnip (KP 671.0), Crooked (KP 718.2), Muskeg (KP 748.1), Salmon (KP 763.1), Necoslie (816.4), Stuart (821.9), Sutherland (KP 855.5), Endako (KP 929.3) and Morice Rivers (1038.0). The drainage in much of the area is trellis shaped rather than being controlled by ridges trending more uniformly across the route.

The Parsnip and Crooked Rivers drain to the north, ultimately into the Peace River system and into the Mackenzie River system. Streams west of the Continental Divide near KP 730 and east of approximately KP 944 ultimately drain into the Fraser River system. Streams in the Interior Plateau Physiographic Region west of approximately KP 944 near Maxan Creek flow into the Bulkley River system and then into the Skeena River.

The area has a typical continental climate: cold winters, warm summers, and a precipitation maximum in late spring or early summer. However, the moderating influence of Pacific air occurs throughout the year, particularly toward the west. The mean annual temperature is approximately 3°C with a summer mean of 12.5°C and a winter mean of -7°C. The area lies partially in the rain shadow of the Coast Mountains. Mean annual precipitation ranges from 250-800 mm. The highest values occur at higher elevations in the west along the Chilcotin Ranges and the lowest values (250-300 mm) occur around the junction of the Chilcotin and Fraser rivers (Ecological Stratification Working Group 1996).

2.6.2 Surficial Geology

The Interior Plateau is underlain by flat-lying Tertiary and volcanic bedrock that forms a gently rolling surface covered by thick glacial drift into which the Fraser River and its major tributaries are commonly incised (Tipper 1971a; Mate and Levson 2000). The topographic relief is generally undulating to hummocky with steeper topography near some bedrock outcrops. Surficial deposits include glacial till with well-developed drumlinoid features, pitted terraces, simple and compound eskers, areas of glacial lake (glaciolacustrine) deposits (Ecological Stratification Working Group 1996) and glaciofluvial deposits primarily along numerous former meltwater channels. The depths of surficial materials are variable with local areas of rock outcrops, but much of the area is underlain by deep till with some areas of deep glaciolacustrine and glaciofluvial deposits (eg., Salmon River, Stuart and Necoslie Rivers, and Endako River valleys).

Preglacial valleys have been infilled in some areas with sediments including bouldery materials, glaciofluvial materials, glaciolacustrine sediments, and till. These valley fill deposits may be a major consideration for directional drilling.

The Interior Plateau can be subdivided into three main geomorphic regions:

1. The Rocky Mountain Trench is crossed near the Parsnip River. The Trench is infilled with old and variable sediments up to many millions of years old.
2. The Interior Plateau proper is characterized by widespread drumlinoid and related glacial linear features. Other terrain conditions include glaciofluvial terraces, eskers, and large areas of level glaciolacustrine deposits. Kettles, eskers and other ice contact features are scattered along the valleys (Tipper 1971a).
3. The Coast Mountains foothills are characterized by higher elevation bedrock controlled topography with hummocky to undulating relief. In general, slope gradients and overall relief are considerably greater than the Interior Plateau proper. Surficial sediments are dominated by glacially derived till and outwash deposits (Mate and Levson 2000). On steeper slope gradients, colluvium derived from the erosion of bedrock and till commonly occur.

Prominent glaciofluvial terraces occur along many of the major valleys. Fluvial and organic sediments are common along modern river drainages and in depressional sites.

2.6.3 Bedrock Geology

The interior Plateau physiographic region is composed of three geologic terranes and includes six significant groups. The terrenes of the Interior plateau include the Cache Creek, Stikine, and Omineca Belts (Journeay et al 2000b, Wheeler et al 1991). The six major tectonic assemblages of the Interior Plateau include the Slide Mountain, Kamloops, Gambier, Cache Creek, Nicola, and Chilcotin. The Pinchi Fault occurs within this region on a northwest\southeast trend and a distinct change in tectonic assemblage occurs across the fault (Journeay et al 2000b; Tipper 1971b).

The Interior Plateau is dominated by volcanic rock types deposited under both marine and non-marine conditions. The Slide Mountain Group is Devonian to Triassic in age and contains ocean margin basin volcanics, primarily comprising pillowed basalt and breccia. The Kamloops Group contains non-marine alkali rich basalt, andesite, and rhyolite arc volcanics (Journeay et al 2000b). The Jurassic to Cretaceous Gambier Group comprises rift volcanics with greywacke, siltstone, conglomerate, and basalt. The Mississippian to Upper Triassic Cache Creek Group contains oceanic volcanics and sediments including basalt and gabbros. The Triassic to Jurassic Nicola Group contains both marine and non-marine arc volcanics and volcanic clastic flows, including andesite and basalt. The Tertiary Chilcotin Group contains non-marine volcanics that are mainly transitional alkaline basalt flows (Journeay et al 2000b).

The rock types that underlie the route are not typically prone to large deep-seated failures. Such failures do occur in the Kamloops Group rocks; however, these rock types do not underlie the route.

Local widely scattered occurrences of Potentially Acid Generating (PAG) rocks may occur in the Interior Plateau area. Acid Rock Drainage (ARD) considerations are discussed in AMEC (2009c and 2009d).

2.7 Coastal Mountains

2.7.1 Topography and Physiography

The Coastal Mountains physiographic region extends from KP 1066.9 to the end of the route at KP 1172.2. This physiographic region extends from sea level to elevations greater than 2700 m. The area is rugged with areas of very steep high slopes, incised canyons and some flat bottomed valleys that are infilled with glaciofluvial or alluvial sediments. Many of the exposed areas of bedrock are rough. Glaciers are still present on some areas of high terrain.

The pipeline route follows major valleys through parts of the area including parts of the Burnie and Clore Rivers on the east side and parts of the Kitimat River and tributaries on the west side. Elevations along the proposed pipeline route through these areas range from 760 to 1375 m (2500 to 4500 ft) on the east side to close to sea level on the west side. The route through the highest part of the Coast Range near Mount Nimbus is proposed to include two tunnels at elevations of approximately 735 to 800 m. Toward the west, the route follows the Hoult Creek valley to the Kitimat valley and crosses the Kitimat-Kitsumkalum Valley, a flat bottomed valley (partially a former fjord) infilled in part with glaciofluvial sediments on the flat Onion Lake Delta. The route turns to the south and runs down the east side of Iron Mountain. South of Iron Mountain, the Wedeene and Little Wedeene Rivers are crossed and the route parallels existing roads along the west side of the valley. South of the head of the inlet, the route runs along sideslopes and benches on the west slope of Kitimat Arm to the Terminal site. The end of the route is at the Kitimat Terminal on the west side of Kitimat Arm, a fjord with rough rock ridges and steep slopes. The terminal is located on a rolling to hummocky upland bench approximately 3 km north of Bish Creek.

Major stream crossings include the Clore (KP 1072.5), Wedeene (KP 1144.5) and Little Wedeene (KP 1148.6) Rivers.

Climatic conditions vary geographically, and are generally wetter and milder on the coast, grading to drier and cooler conditions across the Coastal Mountains toward the interior of the province (Ecological Stratification Working Group 1996). Mean annual temperatures range from 6.5°C along the coast to 2.5°C near the eastern boundary of the region. Mean summer and winter temperatures range from 9°C to 0.5°C along the coast to 11.5°C to -8°C at higher elevations along the eastern boundary (Ecological Stratification Working Group 1996). Mean annual precipitation is highly variable, with values upwards of 4500 mm along the coast and 600 to 1500 mm along the eastern boundary (Ecological Stratification Working Group 1996).

The underlying bedrock includes moderately weak to very strong rock units dominated by volcanic rock types and strong to extremely strong Coast Plutonic Rocks such as granodiorite. Surficial materials include extensive deposits of colluvium and glacial till. Alluvial, glaciofluvial and colluvial fans occur along the edges of the major valleys. At the west end of the area, glaciomarine clay deposits occur below maximum elevations of approximately 200 m. Glaciofluvial and stagnant ice deposits (granular material) are widespread and infill some of the major valleys.

Due to the variable strengths of some of the metavolcanic formations (specifically parts of the Telkwa Formation and some weak metamorphosed sedimentary rocks), recessive weathering of the rock mass has occurred locally in some areas. In general, the depth of cover of till, colluvium and weathered rock is relatively thin. The Clore River has cut a very deep post-glacial canyon in the Telkwa Formation west of the proposed route and has also cut a shallower meandering canyon into the preglacial Clore River valley bottom southeast of the proposed route.

2.7.2 Surficial Deposits

2.7.2.1 General

The Coast Mountains have undergone a number of glacial events, the last of which was the Fraser Glaciation. During this event, the valley glaciers and ice sheets coalesced to produce a significant dome extending from the southern Yukon to northern Washington (Gottesfeld 1985). At the peak of the Frasier Glaciation, ice thicknesses were sufficient to cap much of the Coast Ranges with ice. Subsequent montane glaciation has significantly altered the landscape following the last glacial maximum (Gottesfeld 1985). Small glaciers persist in some of the higher areas.

At the east end of the physiographic region, thin granular till deposits predominate on the uplands. Some of the lowland areas have extensive deposits of glaciofluvial sand and gravel. Minor muskeg infills some depressions. Parts of the Clore River valley upstream of the canyon have undergone extensive erosion of the apparently formerly existing valley infill deposits as a result of the base elevation of the river being lowered by the post-glacial erosion of the canyon.

Typical alpine and valley glacial land forms are present in higher elevation areas including steep topography, cirques and U-shaped valleys. Across high elevation ridges and dissected plateaus, exposed rock is common and many of these areas have very rugged and rough topography. Many of the large U-shaped valleys have been partially infilled with glaciofluvial sediments with some areas of glaciolacustrine and glaciomarine accumulations. Colluvium in the form of scree is common below many of the steep rock slopes. Till of variable thickness, but frequently thin, mantles many of the slopes.

The crossing of the spine of the Coast Mountains will be via two tunnels and so the highest terrain will not be directly encountered.

On the Kitimat side of mountains, surficial geology conditions are dominated by deposits and conditions that occurred during deglaciation. Glacial ice persisted in the Kitimat area to approximately 10,000 years Before Present (BP). Rapid delectation occurred between 13,000 and 10,600 years BP (Gottesfeld 1985) via a series of rapid calving and stagnation events. These short standstill events were marked by the deposition of significant glaciomarine deltas (Clague 1976). Glacial till was deposited directly from the ice, as ablation till when the ice melted back, and as recessional moraine ridges.

As a result of the weight of the glacial ice, the land was isostatically depressed. In addition, sea level was lowered due to accumulation of water in the continental glaciers. As deglaciation progressed, sea level rose and the land rebounded. Sea level rise was more rapid than land rebound and consequently, the Kitimat-Kitsumkalum Valley was flooded to a point north of Terrace (25 km north of the pipeline route) nearly reaching present day Kalum Lake. Maximum sea levels within the Kitimat-Kitsumkalum Valley were reached by 10,600 years BP with flooding to approximate elevations of 200 m asl relative to present terrain elevations (Clague et al 1982). Between 10,600 and 9,300 years BP, the land rebounded rapidly with sea level elevations of 35 m above present sea level at the end of this period (Clague et al 1982). Modern sea level relative to the land was attained by approximately 8900 years BP.

As a result of the marine transgression, laterally extensive deposits of glaciomarine clay occur throughout the Kitimat-Kitsumkalum trough to elevations of around 200 m. In some areas these clay deposits are exposed on surface while in other areas they may underlie subsequently deposited sediments. In many areas, the glaciomarine deposits are thin and interbedded with coarser glaciofluvial and alluvial materials deposited from streams flowing along the valley and down the valley walls. Extensive and deep glaciofluvial deposits occur in the form of terraces, plains and fans, ice contract deposits and glaciofluvial fans and deltas throughout the main Kitimat valley and the lower parts of tributary valleys. As indicated above, these deposits may overlie glacial till and/or be interbedded with glaciomarine clay.

Within the steep glaciated valleys of the Coastal Range, parent materials are dominated by bedrock, weathered bedrock, and colluvial materials. Till and localized glaciofluvial deposits also commonly occur. Recent sedimentation includes the accumulation of alluvium and organic deposits.

The upper Kitimat Valley includes a variety of deposits including till and extensive deposits of glaciofluvial boulders, sand and gravel, colluvium. Exposed bedrock occurs on the upper valley slopes. Glaciomarine sediments occur in the lower part of the valley near the junction with the Kitimat-Kitsumkalum trough, although exposures of the clay are rare along the pipeline route. Fluvial deposits (reworked glacial and deglaciation deposits) occupy much of the valley floor. Modern organic accumulations are also present in depressional and level topography.

2.7.2.2 Glaciomarine Clay

As discussed above, glaciomarine clay is present in the Kitimat-Kitsumkalum trough, including the proposed Kitimat Terminal site on the west side of Kitimat Inlet, and at some locations in the lower parts of valleys tributary to the main Kitimat River valley including the Kitimat River near Chist Creek. The maximum elevation of the glaciomarine clay is approximately 200 m which was the maximum height of the marine transgression, although typically the major concentrations of the clay appear to be below about 185 m elevation.

Some of the marine clay layers may be sensitive or quick. “Sensitive” means that the ratio of peak to remoulded strength is more than four and quick clays have strength reductions of more than 30. However, in the work to date, no quick clay has been identified along the proposed route and it appears that most occurrences are north of the Onion Lake Delta.

The presence of potentially sensitive glaciomarine clay is a result of the deposition process in marine conditions and subsequent leaching by fresh groundwater. The clay was originally deposited under marine salt water conditions during the marine transgression at the end of the last glaciation. As the salty pore water is gradually leached under fresh water conditions, the internal structure between the clay particles may become unstable and susceptible to large strength reductions.

Unlike occurrences of sensitive glaciomarine clays in some other parts of the world, the clay in the Kitimat Valley does not have uniform properties with depth. Rather, weak layers may be present within a much larger thickness of stronger clay, or a weak clay layer may underlie or be interbedded with other deposits such as glaciofluvial sand and gravel.

Numerous slides have occurred in the glaciomarine clay deposits in the Kitimat-Kitsumkalum trough as a result of the presence of the marine clay. Many of the slides are located north of the Onion Lake Delta and thus are not located near the proposed route. Geertsema (2004) has documented numerous slides in the valley north of Kitimat and others are evident from review of airphotos that are not included in his summary. Glaciomarine clay slides have affected local infrastructure including roads and Highway 25 along the east side of the Kitimat valley.

The current routing through the Kitimat-Kitsumkalum valley considered the following criteria with respect to the glaciomarine clay:

1. The proposed route for the east-west crossing of the valley (KP 1122 to about 1134) is on the Onion Lake Delta and is located well north of the break in slope where slide activity has occurred in the past along the south side of the delta.
2. An area of sliding on the edge of the delta is bypassed to the west between KP 1134 and 1137.
3. The north to south route along the west side of the valley was routed along the east side of Iron Mountain away from areas that exhibited evidence of past slide activity based on helicopter reconnaissance. The route along the east side of Iron Mountain is along the lower parts of areas underlain by rock, glacial till or glaciofluvial outwash and generally avoids areas where surficial mapping by Clague (1976) indicates the presence of surficial glaciomarine deposits. A hole drilled by AMEC at about KP 1140.1 on the east side of Iron Mountain near Deception Creek (Borehole R02) did not encounter sensitive glaciomarine clay, although stiff to hard high plastic clay was encountered below sand deposits from 44 m to the bottom of the hole at 66.5 m. Further investigation is recommended in areas where the proposed route might be underlain by glaciomarine clay along the southwest side of Iron Mountain, in the vicinity of the Wedeene River and some areas to the south.
4. South of the Wedeene River, the route also generally avoids areas of mapped occurrences of glaciomarine clay with areas of active sliding.

Further geotechnical work will be required to finalize the detailed routing through the Kitimat-Kitsumkalum Valley with respect to stability conditions and possible occurrences of sensitive marine clay deposits.

2.7.3 Bedrock Geology

The Coastal Mountains physiographic region is underlain by complex geologic conditions. Five primary assemblages occur within the Coast Mountains, including the Hazelton, Kamloops, Skeena, Carmacks, and intrusive Plutonic rocks of the Central Coastal Plutonic Complex (Journeay et al 2000c; Gottesfeld 1985). The Jurassic Hazelton Group has marine and non-marine volcanic complexes consisting of breccia, shale, basalt, and andesite. The Kamloops Group is similar to occurrences of the same rock types in the Interior Plateau and consists of Tertiary non-marine alkali rich basalt, andesite, and rhyolite arc volcanics. The Cretaceous Skeena Group consists of marine and non-marine clastics, including interbedded siltstone, sandstone, and conglomerate. The Upper Cretaceous Carmacks Group contains non-marine volcanic basalt and andesite. The Central Coastal Plutonic Assemblage is mid Jurassic in age and contains a geologically complex sequence of foliated diorite, horneblende-biotite quartz, granodiorite, and quartz diorite (Journeay et al 2000c).

The predominant rock types that underlie the pipeline route include the Skeena Group, Bowser Group, Telkwa Formation (part of the Hazelton Group) and the Central Coastal Plutonic Assemblage. With the exception of Coast Plutonic Assemblage, all of these formations contain

rock types of variable competency on a regional basis. The Telkwa Formation varies from moderately weak to very strong; however, preliminary mapping and drilling investigation results indicate that strong to very strong rock will often be encountered along the tunnels. In general, the plutonic rocks are very strong and competent. There are several regional faults in the area of interest but no faults that are known to be active.

Local widely scattered occurrences of Potentially Acid Generating rocks may occur in the Coast Mountains. Acid Rock Drainage considerations are discussed in AMEC (2009c and 2009d).

2.8 Regional Preglacial Valleys

Prior to the last glaciation, an extensive network of preglacial valleys was eroded into the bedrock surface in Alberta and parts of BC as a result of preglacial stream erosion. As a result of the protracted period over which these channels formed (the last interglacial period was several tens of thousands of years long), the preglacial valleys tend to be much wider than the modern valleys. In some cases, the modern valley closely follows the ancient valley while in other instances; the modern valley may not have the same path or direction as nearby preglacial valleys.

Many of the ancient valleys were infilled during and immediately following the last glaciation with a mixture of glacial till, glaciolacustrine sands, silts and clays and glaciofluvial sand and gravel, possibly containing cobbles and boulders. Often the floor of the valley is overlain by a few meters of cobbly or bouldery sand and gravel that are the fluvial deposits of the original stream deposited prior to the most recent glaciation.

Subsequent to the most recent glaciation, the modern streams have cut down through some of the areas of valley fill, leaving wedges of material along the valley walls (depending on the materials, these wedges of surficial materials may be prone to sliding). Where the stream has not cut down to the elevation of the original valley floor, substantial amounts of valley fill including cobbles and boulders may underlie the modern stream channels or uplands. This material may have several implications for the routing, design and construction of the proposed pipelines including:

1. Slope stability: Weak clay layers within glaciolacustrine valley fill sequences have resulted in numerous large deep-seated slides. The slides are facilitated by the very low shear strength of the clays which may have residual shear strengths (strengths of remoulded material) of about 8° based on past work on glaciolacustrine clays near the route in BC. These low strengths facilitate the formation of very large deep-seated translational slides on weak layers in the glaciolacustrine valley fill. Wherever possible, these large slides have been avoided during routing.
2. Valley fill: Some of the valley fill materials such as loose sand, soft clay deposits or boulders (particularly bouldery deposits along the bottoms of the old channels) may be impediments to directional drilling or may require much longer directional drill holes in order to bypass the problem areas.

3.0 GEOTECHNICAL CONSIDERATIONS

3.1 General

Table B-1 (Appendix B) summarizes geotechnical conditions and preliminary recommendations along the proposed pipeline route. Preliminary recommendations and evaluations are made from a geotechnical point-of-view with respect to crossing methods and preliminary mitigative considerations.

This section (Section 3) discusses geotechnical considerations with respect to the proposed route including the following:

- **Natural Terrain Hazards** (Section 3.2): Summary of various non-seismic terrain hazards that have been identified during routing studies. Terrain risk analysis is discussed in Section 5.
- **Seismic Conditions** (Section 3.3): Summary discussion of seismic conditions and seismically related terrain hazards.
- **Tsunamis** (Section 3.4): Preliminary discussion of marine tsunami waves in the Kitimat Arm of Douglas Channel
- **Acid Rock Drainage and Metal Leaching** (Section 3.5) (ARD); Overall discussion of ARD.
- **Watercourse Crossing Methods** (Section 3.6): General discussion of methods considered relative to geotechnical routing considerations
- **Clore and Hoult Tunnels** (Section 3.7): Detailed discussion of the geotechnical aspects of the tunnels is under separate cover; the discussion in this report is general with respect to the overall route.
- **Rock excavation** (Section 3.8): General considerations with respect to expected rock conditions based on work to date.
- **Potential borrow sources** (Section 3.9): Detailed work on borrow sources has not been done to date. This section provides an overview of potential geologic sources that could be considered for more detailed evaluation in the future.

Details of terrain hazards identified along the route are discussed in Section 5 which further discusses the hazards relative to an overall risk assessment.

3.2 Natural Terrain Hazards

Natural terrain hazards have been identified near some portions of the route corridor and, in particular, are likely to be present to some degree in all areas of steep terrain, deeply incised valleys or other areas of appreciable topographical relief. Terrain hazards have been a major consideration in the routing of the pipelines. In general, the hazards have been avoided where possible. Where it was not possible to avoid an identified hazard, preliminary mitigation methods have been identified (Table B-1). It is expected that evaluation of terrain hazards and potential mitigation methods will continue into the detailed design phases.

The following discussion summarizes principal identified terrain hazards with respect to non-seismic conditions. Other potential hazards related to seismic conditions are discussed in Section 3.3.

3.2.1 Mass Wasting

Mass wasting is the down-slope movement of bedrock and surficial deposits under the influence of gravity. For the purpose of this discussion, mass wasting includes deep-seated landslides, shallow to moderately deep landslides, rockfall, debris flows, avalanches, lateral spreading, lateral stream erosion (scour) and sedimentation, and wind, shallow stream or overland (flow) erosion.

A general discussion on stability issues appears above in the discussion of the Physiographic Regions and stability considerations are summarized in Table B-1 for specific areas along the route. The types of slides and natural mass wasting hazards identified are discussed below.

3.2.1.1 Deep-Seated Slides

As used in this report, deep-seated slides are slides more than approximately 10 to 15 m deep. Deep-seated slides may occur along weak clay layers in both soil and rock such as near-horizontal weak clay layers in glaciolacustrine deposits and weak clay layers in some of the bedrock sequences. Some of the largest slides, such as those along the east side of the Wapiti River, may extend for more than 500 m back from the river and may be several tens to over 100 m deep (these slides were avoided during routing studies). Many of the deep-seated slides move relatively slowly with creep rates of only millimetres per year in some cases. Increased water pressures along the slide surfaces or toe erosion may result in large increases in movement rates, in excess of several meters per day for short periods of time in some circumstances. The higher movement rates are generally most likely to occur on slopes at angles well above the residual friction angles (slopes steeper than say, 10 to 12°). Where ongoing movement has resulted in the deep-seated slides retrogressing to overall slope angles approaching the residual friction angle, the chances of rapid large movements are thought to be generally low in the absence of major topographic changes such as undercutting of the toe of the slope.

Deep-seated slides are present on or near several of the major river crossings including the Little Smoky, Smoky, Wapiti, Stuart, and Morice Rivers. Wherever possible, avoidance of deep-seated slide areas is the preferred option, but it may not be possible for all of the river crossings due to the prevalence of such slides. Where the pipelines cross a slide, mitigation work and monitoring may be required depending on the situation. Directional drilling or possibly other trenchless methods such as microtunnelling under the slide are other crossing methods that may be considered depending on other geotechnical and design factors.

3.2.1.2 Shallow to Moderately Deep Slides

Shallow to moderately deep slides (up to 10 to 15 m deep) occur within many of the weaker soil or rock materials and are often located on steeper slope segments than the deep-seated slides. In addition, shallow to moderately deep slides may occur on top of the deep-seated slides as a result of the disturbance and cracking in the shallower materials caused in part by underlying

deep-seated movement. The overlying slides may have much higher rates of movement than the deep-seated slides and may respond rapidly to changes in pore pressure conditions. Shallow to moderately deep slides may occur in some of the glaciomarine clays near Kitimat where very large strength losses may occur in some sensitive zones. Shallow slides may be a locally significant source of sedimentation. Mitigative measures for shallow to moderately deep slides include surface and groundwater management, avoidance where possible, grading, and/or buttressing the toe.

Earthflows consist of shallow (typical depths up to possibly 10 m or more) masses of completely re-moulded soil that “flow” slowly down slope. No large earthflows have been identified to date along the proposed pipeline route during the geotechnical work, although such slides have been found in the past in some of the glaciolacustrine soils in British Columbia. Earthflow movements have also occurred in some of the glaciomarine slides north of Kitimat. To the extent possible, where areas prone to such movements have been identified, they have been avoided during routing.

Groundwater blow-off failures (Cavers, 2003) are groundwater induced failures that lead to extreme piping (internal erosion) of the soil. They typically form in bedded glaciofluvial deposits along steep slope segments where groundwater flows from permeable layers becomes blocked. This is commonly associated with the near surface soil being reworked by vegetation, creep, frost or other mechanisms. When the stored groundwater builds up sufficient pressure, the surficial layers may be blown off and large amounts of stored groundwater drain rapidly, causing piping and surficial erosion of a canyon with an amphitheatre-shaped head scarp. Subsequent sloughing may also occur. Groundwater blow-off failures are common on some of the glaciofluvial terraces in central British Columbia. Steep terrace fronts have been avoided during routing where possible and no examples of large blow-off failures along the route are presently known. Some small to moderate sized failures have occurred near the Athabasca River crossing, at a few locations in the upper Kitimat valley and along Klo Creek. Mitigative measures, if required, include avoidance, groundwater drainage controls, and soil retention techniques (for example by rock mats over geotextile).

3.2.1.3 Debris Flows

Debris flows can occur when “debris” (accumulations of fluvial and colluvial materials along streams) is mobilized by high stream flows and/or groundwater seepage. The resulting mixture of water and soil can sweep down the stream channel, causing erosion in some areas and deposition in other areas. A few streams in the Rocky Mountains and Coast Range may be subject to debris flows. With respect to the proposed pipelines, the main hazards include erosion at the stream crossing and avulsion where debris is deposited and blocks a channel of a creek, causing a change in channel location. Both forms of erosion could potentially result in pipeline exposure, coating damage and/or pipeline damage. Rupture as an immediate consequence of a debris flow is considered to be unlikely based on past experience with similar events.

3.2.1.4 Rockfall

Rockfall includes both rockfall from rock cliffs and falls of boulders from very steep colluvial or till slopes. Rockfalls are a hazard in a few locations near the proposed route. Most of the rockfall areas identified to date have been in the Coast Mountains. Other areas prone to rockfall may occur on the east side of the pass through the Rocky Mountains. In the worst case, very large rock blocks falling with high energy directly on the buried pipelines could result in failure, but the more likely consequence is denting and/or coating damage. Mitigative measures will depend on the extent of the problem and include avoidance, scaling, anchoring, extra depth of cover, deflector berms or fills and/or special protection measures.

The discussion above is with reference to naturally occurring rockfall; however, high cut slopes, such as sidehill cuts in rock, may trigger rockfall events on the steepened slopes or at the crest of the cut from surficial materials. Rockfall from high cuts will require special consideration during design. Mitigative measures include deflection berms, deflection fills over the pipelines, removal of problem materials by scaling, anchoring, rockfall catchment fences and similar installations and special protection measures including buried reinforced concrete slabs.

3.2.1.5 Avalanches

Avalanches include the movement of snow, and movement of sediment and debris by snow down a slope. Even large avalanches do not usually directly affect buried pipelines; however, above ground structures such as aerial crossings, valves or expansion bends could be affected. Avalanches may also block stream channels, subsequently resulting in avulsion or downcutting erosion. Changes to surface drainage conditions following major avalanches coupled with periods of rapid snow melt are an important consideration that could potentially result in exposure of the pipelines if suitable mitigative measures are not undertaken. Avalanches across access roads could also affect the ability to access and respond to various situations. The direct and indirect consequences of avalanches may include denting or mechanical damage, coating damage or exposure. Avalanche impact on above-ground structures could potentially include rupture, but no such areas are presently known and avalanche paths have been avoided during planning for above-ground structures. Mitigative methods include avoidance of above ground pipeline structures in vulnerable areas, detailed analysis of avalanche conditions, deep cover, deflector berms, various avalanche control techniques and consideration of the possible secondary effects of stream diversions.

3.2.1.6 Mountain Spreading (Sackung)

Mountain spreading (sackung) failures have been identified in parts of the Rocky Mountains and foothills. While the mechanism may vary, these areas of terrain movement typically involve strong rock over weak rock on high steep slopes. The underlying weak rock may squeeze plastically, inducing lateral creep movement that involves slow protracted movements. Toppling failures in the strong rock may occur as the rock is moved laterally towards areas of steeper slopes. This failure mode occurs in some areas near Tumbler Ridge and in parts of the Rocky

Mountains south of the route; however, no sackung or mountain spreading failures are known to AMEC in proximity of the route. Since no instances of sackung movement have been identified, the hazard will not be further considered in this report.

3.2.1.7 Lateral Spreading

Lateral spreading involves lateral movement of ground typically but not necessarily triggered by a seismic event. Movement might occur on a weak layer, such as a weak sensitive glaciomarine clay layer in the Kitimat valley area or potentially due to liquefaction of underlying loose materials such as sand (no such areas are known along the pipeline route). A lateral spread could involve large lateral movements and, as such, could have major impacts on the proposed pipelines. Principal mitigative measures include avoidance of areas prone to such events (routing), design of the pipeline systems to withstand the movements, possibly decoupling the pipelines from the soil movement using surface pipeline technology and ground improvement or drainage.

3.2.1.8 Stream Erosion and Sedimentation

Stream erosion includes the possibility of lateral erosion, reoccupation of sub-channels and/or downcutting or scour exposing the pipelines. The possibility of secondary interactions such as lateral erosion triggering slope instability may also occur. Lateral erosion conditions will be considered during detailed design of trenched crossings. Mitigation methods include installing the pipelines below the depth of potential scour across the affected areas, directional drilling, micro-tunnelling and similar methods to go under the area, or possibly an aerial crossing above the area affected. Other mitigative methods include riprap, groynes, spurs and other similar installations, that can often be installed in the dry rather than requiring in-stream work.

Avulsion (channel switching such as on alluvial fans) is a special case of stream erosion. Where avulsion occurs on a large fan, the stream may relocate to a different part of the alluvial fan, potentially 100 m or more from the original stream crossing, possibly causing downcutting erosion or sedimentation over an area remote from the original crossing. Avulsion on alluvial fans may be triggered by a variety of events such as high flows (rain and/or melting snow), ongoing deposition along the stream channel or debris flows or avalanches blocking the channel. Avulsion may be an important consideration for a few stream crossings east of Tumbler Ridge near Kinuseo Creek, along parts of the upper Kitimat Valley and in a few other localized areas along the proposed route. Mitigative measures include directional drilling or deep trenching across the fan, crossing the fan near the head where the lateral extent of avulsion is limited, or avoiding areas that may be prone to avulsion (routing).

3.2.1.9 Wind and Shallow Stream or Overland Erosion

Wind and water erosion are two of the main agents of siltation, which is a potentially widespread concern along the pipeline route, particularly during and immediately following construction, if suitable mitigative measures are not undertaken. The main consequences are environmental including potential impacts on streams and fish. Mitigative methods include routing to avoid areas of particular concern, detailed consideration during grading designs, ground and surface water control, revegetation, erosion matting, straw/hay mulching.

3.2.2 Settlement

For the purpose of this study, settlement includes both consolidation and karst-induced settlement or displacement.

3.2.2.1 Consolidation Settlement

Normally consolidated silt, clay or peat may be subject to settlement where additional loading, such as fill, is placed. This is an infrequent hazard along the proposed pipeline route, based on present conditions, although it could potentially occur in a few areas due to placement of access fills across muskeg and in the future due to road construction, site development or other causes.

3.2.2.2 Karst-induced Settlement or Displacement

Apparent dolines (down-dropped areas formed by karst processes, for example, solution of limestone) have been identified at some locations through the Rocky Mountains. Sink holes (smaller down-dropped areas or areas where loss of ground has occurred) are also present. Ground subsidence has also induced the formation of multiple scarps and/or other slope movements that may have associated lateral movements in a few areas. One primary mitigation method is avoidance during routing – the method used for all known areas along the route. Mitigative measures, if required, include additional investigation, special backfills, designs to allow small ground movements to occur without affecting the pipelines, surface pipelines and monitoring.

3.3 Seismic Conditions

3.3.1 Geologic Setting

The geologic and seismic conditions near the west end of the proposed pipelines at the BC coast differ from those along the coast farther south. To the south, seismic conditions are dominated by the oceanic Juan de Fuca plate which is subducting (sliding) beneath the continental plate. In contrast, from northern Vancouver Island to the Queen Charlotte Islands and including the area west of Kitimat, the oceanic Pacific Plate is sliding to the northwest at about 6 cm/year relative to the North American Continental Plate along the Queen Charlotte Fault (Natural Resources Canada 2009, Internet site). This fault is active and the largest historical earthquake in Canada occurred on this fault on August 22, 1949 (magnitude 8.1). However, since the Queen Charlotte Fault is over 300 km west of Kitimat, the level of ground

shaking that would be produced by a large magnitude event, while appreciable, would be much less than would be produced on land by an equivalent earthquake off the south coast of BC on the subduction zone.

Recorded earthquakes in western Canada are summarized on Figure 3.1, from Atkinson (2009). Most of the events along an approximately northwest-southeast line west of the Queen Charlotte Islands are associated with the Queen Charlotte Fault. Farther east, there are fewer and much smaller events that are likely located on crustal faults. The largest earthquake recorded in the southern Cordillera was a magnitude 6.0 in 1918 near Valemount in the Rocky Mountain trench almost 300 km south of the proposed pipelines alignment. In 1986 a magnitude 5.5 earthquake occurred near Prince George (60 km south of the proposed route) causing some minor damage (information from GSC website).

East of the Rocky Mountains, the magnitudes of the recorded earthquakes again decrease. There have been some magnitude 4 to 5 events north of Fort St. John that are likely related to water injection in connection with oil recovery from wells. Similar magnitude 3 to very occasional magnitude 5 events have been recorded in Alberta.

Correlation of earthquakes with active faults is not possible within the area crossed by the pipelines and no active faults are known in near the proposed route. Within the study area, earthquakes typically occur at depths of 5 to 20 km on faults that have no surface expression. Furthermore, faults mapped on the surface in western Canada were formed hundreds of thousands to millions of years ago and bear little relation to current seismic activity. Thus there is no clear-cut relationship between observed faults and seismicity and the pipeline route does not cross any known active faults that are exposed at surface.

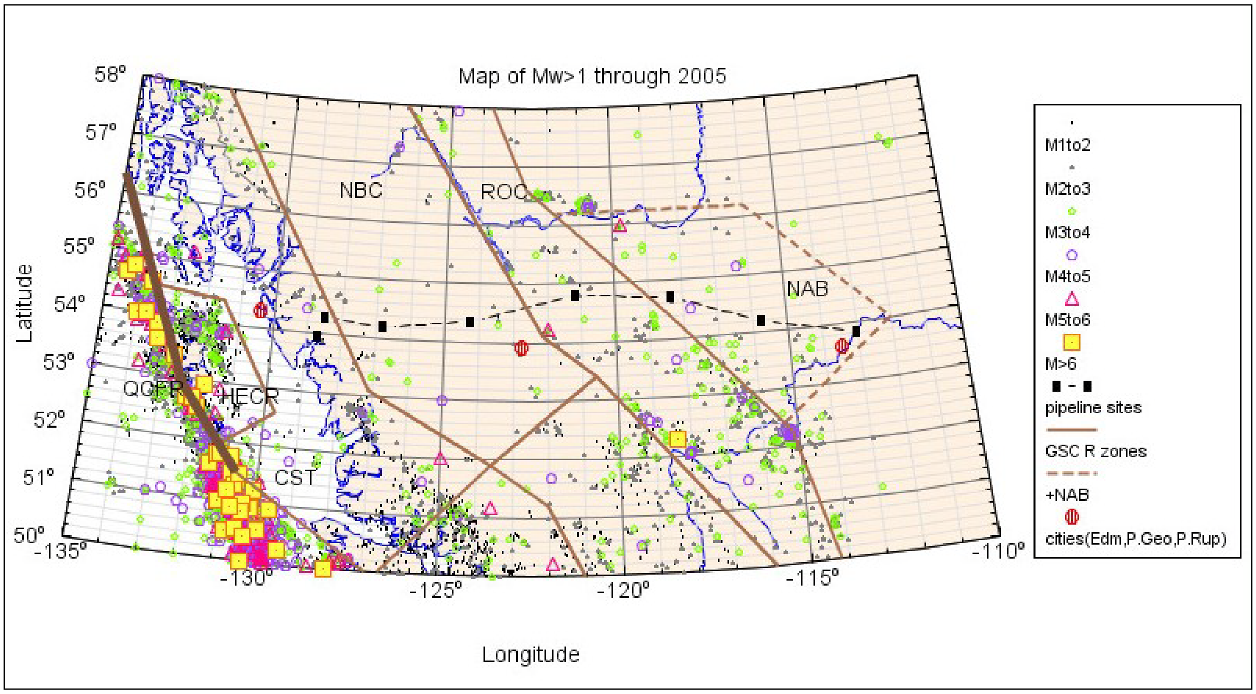


Figure 3.1 Recorded Seismicity in Western Canada

From Atkinson (2009) – Recorded seismicity (M>1) through 2005 together with the GSC R-model source zone models used in the national seismic hazard maps and adopted for Atkinson's study. An additional source zone for Northern Alberta (NAB) was defined in Atkinson's study and is shown with dashed lines. Black symbols indicate study sites and are referenced as Sites 1 to 8 in this discussion from west to east. Red symbols are cities (Edmonton, Prince George and Prince Rupert, from east to west). Note the absence of any large recorded earthquakes near the proposed pipeline route.

3.3.2 Estimates of Ground Motion

Seismic hazard analyses in Canada are based on probabilistic concepts which allow incorporation of both geologic interpretations of seismic potential and statistical data regarding the locations and sizes of past earthquakes. Details of the calculation methods are provided in Atkinson (2009). The methods used by Atkinson were similar to those used in the National Building Code of Canada (NBCC) 2005.

During the preparation of the revised NBCC in 2005, the seismic modeling methods were updated relative to those used in the previous work which was published around 1985. Changes were also made to the design return periods recommended for structures constructed to the NBCC requirements. Prior to the 2005 NBCC, the design earthquake return period under the code was 475 years (probability of occurrence of 10% in 50 years). Under the NBCC 2005, the design return period is recommended to be 2475 years (2% probability of occurrence in 50 years). It should be noted that this change has not been uniformly applied to structures

including highways and pipelines that are not required to be constructed to the NBCC. For example, some recent lifeline structures designs, such as some BC Highways, have used a design return period of 475 years. Another major change in the 2005 seismic models was the incorporation of new seismic knowledge, such as the so-called mega-thrust earthquakes on the subduction zone west of Vancouver Island (the subduction earthquakes on the south coast do not have a major impact on the proposed pipeline route).

The detailed requirements of the specific code to be used for design of the pipelines and other structures should be consulted for design requirements. Note that the 2005 NBCC recommends spectral acceleration values to be used for the design of structures. Spectral accelerations are the acceleration values that would be experienced at different vibration frequencies. The spectral acceleration values may be higher or lower than the Peak Ground Acceleration (PGA) values quoted below, depending on frequency (the applicable frequency depends on the structure). PGA is convenient as a "single point" comparison and is also used for geotechnical analyses. PGA values from Atkinson's results for the eight sites shown on Figure 3.1 are summarized below. The values quoted are for Soil Type B (soft rock).

Site (Fig 3.1) West to East	1	2	3	4	5	6	7	8
PGA (%g) (1:2500)	12%	10%	3%	2%	8%	7%	6%	5%

By comparison, the PGA for Vancouver is 46%g (Soil Type C – dense soil, NBCC 2005).

Seismic conditions at the west end of the proposed route might be characterized as moderate. To the east, the PGA values decrease to low but not zero values. The implications for the pipelines are discussed below, but are not expected to be major, providing that appropriate design measures are used.

3.3.3 Natural Hazards Due to Seismic Events

The seismic conditions are not expected to be a major factor in terms of natural terrain hazards along the route and the design of the mainline pipelines. The following points discuss some of the geotechnical considerations with respect to seismic events:

1. Seismic shaking in terms of pipeline response: The predicted level of shaking is relatively low in terms of pipeline response. There have been no failures of major cross country buried welded steel pipelines due to seismic shaking without associated soil movements (e.g., ASCE, 1984 and Honegger and Nyman, 2004) and the level of seismic shaking for the proposed pipeline route is much lower than has been experienced on other mainline welded steel pipelines in other parts of the world. Providing that there is not lateral movement of soil or rock (such as a slide or lateral spread), the mainline welded steel pipelines will be highly resistant to failure during a seismic event. Therefore, providing that the engineering design and construction takes appropriate account of terrain conditions, seismic shaking and other seismic design aspects, the level of shaking is not of major geotechnical concern to the mainline pipelines.

2. Terminals, pump stations and pipeline tie-ins: Terminals, tanks, pump stations and all other structures should be appropriately designed with respect to seismic conditions. With respect to the pipelines *per se*, it is noted that one area that will require appropriate design consideration are connections to the pipelines such as “T” junctions where another pipeline joins the main pipelines, tie-ins of pumping stations or valves. Under seismic shaking, the different pieces of pipe or facilities may move in different directions. Other portions of the pipelines that may require specific seismic design considerations include above ground pipeline segments possibly including aerial crossings, pipeline segments through the two proposed tunnels and possibly above ground segments across slide areas.

3. Liquefaction and lateral spreading: The level of shaking could be capable of inducing liquefaction of loose sediments at the west end of the proposed alignment should the pipelines cross such sediments. Sediments potentially susceptible to liquefaction could include some recent alluvial deposits in the lower Kitimat Valley. Lateral spreading could also potentially be induced in certain glaciomarine clay deposits. Strength losses might also occur in susceptible zones in marine clays, potentially resulting in low angle slides in some deposits. Table B-1 notes areas where liquefiable sediments or areas prone to spreading/sliding due to underlying marine clays might potentially occur and provides potential mitigative alternatives. Liquefaction and lateral spreading are expected to be examined further during future geotechnical investigations at the time of detailed design work.

4. Mobilization of landslides due to seismic shaking: Seismic shaking could potentially mobilize landslides or rockfall. Such movements would most likely occur on pre-existing slides or on terrain susceptible to such failures and would involve movements of existing slides or areas prone to failure such as rockfall. In general, slope stability is a major geotechnical consideration along the proposed pipeline route and terrain susceptible to such movements would most likely be considered susceptible to movement under non-seismic conditions. The pipelines have been routed to avoid areas where slope stability is a problem wherever possible. Where this cannot be done, mitigative measures are planned to be further considered during detailed design. Therefore, while seismic slide mobilization will be considered further during ongoing terrain evaluations, it is not likely to have a major influence on routing or the mitigative measures considered since the issues will be covered by the non-seismic evaluations.

5. Tunnels: As indicated above, the pipeline supports through the tunnels will require appropriate seismic design. Tunnels are, however, very resistant to seismic movements and, as a result, the seismic motions are not expected to result in any unusual tunnel support requirements.

6. Tsunamis: Tsunamis are discussed in the following section.

3.4 Tsunamis

A tsunami is a series of waves with a long wave length and period, generated in a body of water by an impulsive disturbance that displaces the water. Examples of such disturbances include: some types of subaqueous fault movements (usually associated with large earthquakes); landslides, including subaqueous failures; terrestrial landslides entering a body of water; submarine volcanic eruptions; and meteorite impacts. Meteorite impacts, which are extremely rare events, and volcanic eruptions, not expected in the local geological environment, will not be discussed further.

3.4.1 Seismically Generated Tsunamis

Submarine normal or reverse fault movements can cause a vertical displacement of the entire water column that can then propagate as a series of waves. Large tsunami events have occurred at many locations around the Pacific Basin including very large events generated by the 1700 subduction earthquake on the Cascadia Subduction Zone west of Vancouver Island; however, it is probable that the North Coast fjords are protected to a large extent from Cascadia subduction zone tsunamis, though some effects (not yet modeled) would probably be felt as a result of refracted waves. There are no known active faults within or near Douglas Channel and Kitimat Arm that would be capable of generating a tsunami.

Recently published papers have provided additional details on the potential impacts of seismically generated Pacific Basin tsunamis on the proposed dock facilities located in deep water along Kitimat Arm. A recently published paper (Rabinovich et al., 2008) reports several small tsunamis (11-23 cm) from sources such as the Explorer Plate (north of the Cascadia Subduction Zone) and the Queen Charlotte Fault related to moderate earthquakes (M = 6.1-6.6) between 2001 and 2004.

An evaluation of tsunami amplitudes for the British Columbia coast, that includes the North Coast area, was undertaken by Dunbar et al. (1989) but involved only modeling of distant tsunamis from four sources: Alaska (Prince William Sound), Chile, Shumagin Gap (Alaska) and Kamchatka. The results of their modeling shows that maximum expected tsunami amplitudes (deep water) are 1.9 m in Kitimat Arm, originating from an event in the Shumagin Gap, Alaska. The water rise and subsequent fall would occur over a period of about an hour. These amplitudes are for a wave in deep water in the inlet and do not include any estimates of run-up. Run-up may be more significant in shoal areas or bays than along areas of deep-water coastline along Douglas Channel and Kitimat Arm.

Current velocities associated with these offshore tsunamis would be small near Kitimat, being between 0.02 and 0.03 m/s (0.04 to 0.06 knots). In central Douglas Channel, however, the current velocities would be higher, between 0.36 to 0.46 m/s (0.7 to 0.9 knots). It should be noted that the current velocities vary with the cross-sectional area of the fjord and the distance from the entrance. Thus, if there is a narrowing of the fjord along its length, the current velocities will increase; this is less of an issue along Douglas Channel than in other inlets along

the B.C. coast (e.g., Alberni Inlet) where velocities can be many times higher in the narrow constrictions than along wider parts of the inlet.

Conclusions from the work to date include:

1. For vessels underway, seismically generated tsunamis should not generally pose a hazard as they will be seen as simply a slow rise and fall of a few metres over the course of an hour or so. The minor currents associated with these tsunamis would not pose a threat to the passage of a vessel through the central and upper reaches of Douglas Channel and Kitimat Arm. At present there are no estimates of tsunami amplitudes and current velocities at the entrance to Douglas Channel.

2. Similarly, the siting of the proposed marine terminal facilities along a stretch of deep-water coastline along Kitimat Arm would appear to be at little risk of direct damage from such tsunamis.

3.4.2 Slide Generated Tsunamis in Kitimat Arm – Background

Landslide-generated tsunamis can be caused both by subaerial landslides that enter a standing water body and by subaqueous (underwater) slides. There have been two subaqueous failures in the northern part of Kitimat Arm that have resulted in tsunamis in 1974 and 1975. No sources of subaerial landslides that could generate a large tsunami have been identified in Kitimat Arm.

On October 17, 1974, shortly after low tide and immediately following unusually high flows in the Kitimat River an approximately 20 ft (6.1 m) high wave occurred. The river flows were the highest on record to that date (10 years of record to 1974) and correlation with other river flows suggests that they were probably the highest flows over a period of at least 25 years. The initial occurrence at Kitamaat Village on the east side of the arm was reported to be a wave trough indicating that the wave was moving toward the west. This wave has been associated with an underwater slide at the northeast corner of the arm. There was no reported damage to wharves in the area, although the wave did loosen the moorings of a barge and damaged boats in nearby marinas.

The second significant tsunami event in the Kitimat Arm area occurred on April 27, 1975 at about 10:05 am, shortly after low tide. The wave was approximately 25 ft (7.6 m) high. The slide that caused this failure was apparently associated with construction activities, specifically fills placed at Moon Bay at the northwest corner of the arm. By the end of January 1975, Rivtow Straits had built a timber crib wharf structure (75m x 20 m) at Moon Bay, on the west side of Kitimat Arm. The face of the crib was 6 to 7.5 m high with fill having been emplaced outward from the beach to create a loading platform. At the time of failure, in late April, Rivtow Straits was in the process of constructing a breakwater from rockfill and dredged material obtained from the shallow subtidal zone just seaward of the construction site. The breakwater was below the high tide level at the time of failure. The failure started at the breakwater and within two minutes had propagated around the shoreline to the crib wharf area which was engulfed in the failure and swept away. The failure, which took place in soft cohesive marine clay and included

material from the delta, ran down the sidewall of the arm and several kilometers down the arm. Retrogressive failures continued through April 28 and included subaerial erosion but caused no tsunamis. Direct damage was $1.32 million (1986 dollars).

3.4.3 Conclusions and Comments

Both the 1974 and 1975 tsunamis occurred within a period of about 6 months and were a result of relatively large slides of cohesive materials from the sidewalls of the arm close to the Kitimat Delta.

The 1974 event appears to be have been associated with unusually high flows in the Kitimat River and extreme low tides. The slide from the northeast corner of the inlet extended for several kilometres down the inlet, as indicated by underwater bathymetry.

The 1975 event was similar to other significant coastal tsunamis that were caused by submarine landslides, resulting from placement of fills. Comprehensive geotechnical investigations, design and planning prior to placing large fills in coastal environments would be a key aspect in the future to avoid triggering a major marine slide that could potentially generate a tsunami. Such work would be expected to meet current engineering practice standards.

For a submarine slide to generate a tsunami, the slide must displace a large volume of water sufficiently rapidly that a wave is created. In order to accomplish this displacement, the slide mass must move initially as a block which requires that the slide mass moves coherently. Thus, cohesive material is capable of generating a tsunami, while slides in cohesionless material that rapidly become dispersed, are not. From a practical point of view in Kitimat Arm, slides in clay materials from the sidewalls are capable of generating a tsunami under the correct circumstances, while slides from the delta front are typically not.

Work to date, including review of recently acquired Canadian Hydrographic Service (CHS) data, has demonstrated that there have likely been only two large rapidly moving submarine landslide events in cohesive materials in the northern part of Kitimat Arm. The traces of large slides would remain visible in the bottom sediments of the arm for at least several hundred years and no additional tracks or evidence of large cohesive slides has been found. While there is one additional large slide track on the delta front near the Moon Bay failure, there are no credible reports of a third tsunami and so, if the slide occurred separately from the 1975 Moon Bay failure, failure of the predominantly granular material did not create a significant wave, as would be expected from the characteristics of submarine granular slides.

The following points summarize the conclusions of the work to date:

1. The hazard from earthquake generated tsunamis appears to be low. Based on modeling, it appears that past offshore seismically generated tsunami events would have generated a

rise of about 2 m over a period of about 0.5 hour with associated current velocities less than 1 knot.

2. No subaerial slide areas have been identified on the inlet side slopes that would be capable of generating a sufficiently large slide mass traveling at a sufficient velocity to create a tsunami of a height that could pose a problem at the terminal site.
3. Tsunamis generated by local underwater slides are possible in Kitimat Arm. Two events occurred over a six month period in 1974-1975. These two events appear to have been the only significant events over a very long time period – at least several hundred years.
4. The highest tsunami recorded in Kitimat Arm (1975 event) was associated with the placement of substantial fills and a large underwater slide. The 1975 event was apparently caused by construction activities and human triggering of similar events in the future can be avoided by appropriate engineering investigations and design.
5. Work to date suggests that the potential for a naturally occurring tsunamigenic slide in Kitimat Arm is low. Future work to confirm this preliminary assessment will include review of the likely magnitude and frequency relations for potential future tsunami events relative to the terminal facilities.

3.5 Acid Rock Drainage and Metal Leaching

Acid Rock Drainage (ARD) occurs when sulphide and other related minerals in rock undergo a complex chemical oxidation process producing sulphuric and other acids. A related phenomenon involving heavy metal leaching (ML) may also occur. In unfavourable cases (i.e., where ARD actually occurs beyond the bounds of the rock mass or spoil), there may be two main outcomes including acidic ground or surface water drainage and the mobilization, transportation and deposition of metals and related compounds. The main components of the ARD process include sulphide bearing minerals, water and oxygen. Significant increases in production rates may occur when the minerals are exposed to weathering as a result of rock breaking and excavation processes. ARD can potentially occur on both the broken and excavated rock materials and on trench walls, rock cut faces and other freshly exposed rock surfaces in largely intact rock masses. Metal leaching can also occur, either in conjunction with acid conditions produced by ARD, or independently where appropriate heavy metal concentrations and conditions exist.

ARD has been a concern for many years as a result of the potential generation from mining spoils and mines where high concentrations of sulphide minerals occur. More recently, the potential for generation from civil projects involving rock excavation has been recognized.

The degree to which ARD may be a concern depends on several issues including:

1. The concentrations and particular mineral species present.
2. The type of host rock and the types of rock mixed with the parent material during disposal or trench backfilling. Some rock types such as limestone are natural buffers against acid generation.

3. The ARD generating potential of the materials involved. For example, a small amount of pyrite (an iron sulphide) may be highly diluted within a large excavated volume of rock and may not be an overall concern. By contrast, a large volume of rock bearing relatively small concentrations of pyrite may be a major concern due to the total volume of material and the overall acid generation potential.
4. In a very few cases, naturally acidic water may be encountered in springs (either hot or cold); however, no such springs have been identified along the route.

Office and field studies of ARD and metal leaching potential along the proposed route are discussed in AMEC (2009c and 2009d). Overall, on a regional basis, rock types and geological conditions potentially resulting in ARD conditions occur west of the Kinuseo Creek crossing and more particularly west of the Murray River crossing (Rocky Mountains, Interior Plateau and Coast Mountains Physiographic Regions). However, most of the ARD occurrences are likely to be of limited extent with a few occurrences possibly extending for a few kilometres along the route. Moreover, in several areas where ARD potential conditions may occur in the bedrock, the grade and trench excavations may be located in surficial materials (glacial till or other unconsolidated materials). Where fresh rock exposures are not generated during the work, potential generation of ARD by the Project will not be a concern regardless of the underlying bedrock geological conditions.

3.6 Watercourse Crossing Methods

A variety of methods have been considered for construction of watercourse crossings including open cut crossings (i.e., a trenched crossing without isolation), isolated crossings (trenched crossings with isolation), directionally drilled crossings, aerial crossings, and other trenchless methods such as microtunnelling. Isolation methods considered have included dam and pump (stream flows generally less than 1 m^3/s), flume (stream flows generally less than 5 m^3/s) and superflume and double superflume methods (stream flows generally less than 8 to 10 m^3/s). Trenchless methods may include horizontal directional drilling (HDD), microtunnelling, boring or other methods and aerial crossings. The final choice of crossing method will depend on a number of factors and input from a wide variety of expertise. The summaries in this report (Table B-1) consider hydrotechnical and geotechnical aspects only and should be considered preliminary.

3.7 Clore/Hoult Tunnels near Mount Nimbus

The proposed route crosses the spine of the Coast Mountains via two tunnels generally located west of the Clore River running under high terrain near Hope Peak west of the Clore River Canyon and Mount Nimbus. The geotechnical background for the tunnels is summarized in a separate report (AMEC, 2009a). It is expected that further refinements to the proposed alignments near and through the tunnels will occur as ongoing studies are undertaken.

3.8 Rock Excavation

The following comments pertain to rock excavation.

1. Rock underlying the Eastern Alberta Plains and some of the rock underlying the Southern Alberta Uplands is expected to be mostly rippable during excavation. Some of the sandstone rock underlying the Southern Alberta Uplands (e.g., Paskapoo sandstone) is sufficiently hard and strong that blasting will be required in local areas. In marginal cases, it may be possible to rip the rock for grade excavation but confined areas such as the trench may require blasting to loosen the rock.
2. Most of the rock underlying the Southern Alberta Uplands and the much of the rock underlying the Alberta Plateau is stronger than the rock to the east and the proportion of rock requiring blasting will be much higher than to the east. However, in this area, shale rock will likely still be rippable, at least for grade excavation. Strong rock types such as sandstone, conglomerate, limestone and some siltstone will require blasting as will most of the shale interbedded with strong rock types.
3. In general, almost all of the rock encountered in the Rocky Mountains and to the west will require blasting. The occurrence of chert and quartzite in the Rocky Mountains should also be noted. These rock types are usually more difficult and expensive to drill and blast.

In addition to blasting, other forms of rock excavation could be considered such as the use of rock saws or hoe rams/breakers. For smaller trenches, rock saws have proven capable of excavating the Dunvegan Formation sandstone (one of the harder sedimentary sandstone rocks east of the Rockies). They may not be economically capable of excavating harder metamorphic or intrusive rock types such as gneiss, granodiorite or quartzite in a large diameter pipeline trench; however, development of this technology is ongoing. Unfavourably high wear might occur in rocks that contain significant amounts of chert or quartz. If use of rock saws is considered, field trials in various rock types are recommended since at present there is little experience in the rock types under discussion with the large saws that would be required for the considered pipeline diameters.

Large high energy hoe rams or breakers would be physically capable of excavating grade rock where suitable closely spaced joint patterns exist combined with at least two free faces. In general, hoe rams are not practically suitable for trench excavation since the rock pieces are too confined to be readily loosened and removed.

3.9 Potential Borrow Sources

Potential borrow sources have not been examined to date from a geotechnical point-of-view. In general, many of the potential sources near the pipelines have been examined by local users in the past and many have been used in the past or are actively in use at present. In general, potential borrow sources along the alignment include the following:

1. Alluvial and glaciofluvial terraces: These sources, which include sand to gravel and cobbles, are present in various locations along many of the large river valleys in Alberta and BC. Glaciofluvial deposits also occur outside of the confines of the present large river valleys in some areas.
2. Alluvial and glaciofluvial fans: Alluvial and glaciofluvial fans deposited into larger valleys occur in the Rocky Mountain foothills and areas of higher topography in BC. The resources tend to be variable, even within a single source, but in some areas the glaciofluvial fans, in particular, form a significant resource.
3. Glaciofluvial outwash plains: Glaciofluvial outwash plains and extensive terraces occur in the Interior Plateau area of BC. Some sources may contain very large volumes.
4. Kames, eskers and other ice-proximal deposits: In the Interior Plateau and Coast Range, deposits of granular material formed by short transport from the ice front may be potential granular resources. Esker deposits occur in both BC and Alberta and are often sorted and may form high quality sources. In Alberta, kame deposits tend to have high silt and clay contents, but the parent rock materials in parts of BC were much stronger and so these relatively unsorted deposits may be useable for borrow resources.

In many cases, local resources may already be permitted for production. Further work would be required to determine availability and location of potential granular resources, if required.

4.0 TERRAIN HAZARDS AND RISK ANALYSIS

4.1 General

The section provides a detailed summary of the significant terrain hazards identified during geotechnical and other terrain studies to date along the proposed route and also provides a qualitative risk assessment overview of geotechnical and seismic issues with respect to the proposed pipelines.

The assessment is intended to provide an overall qualitative geotechnical assessment of potential terrain hazards along the proposed pipeline system derived using engineering judgment. The assessment was primarily directed at geotechnical issues that could affect pipeline integrity. Thus, for example, issues such as minor erosion or minor sedimentation were not directly included in most cases in the hazard assessment. Preliminary mitigative recommendations for minor erosion or sedimentation are included on Table B-1, are discussed further in Section 6 of this report and will be further developed during detailed design.

The results of the risk assessment are summarized on Table C-1 (Appendix C) and on Figures 4.1 to 4.7. Figures 4.1 and 4.2 present Risk Assessment Matrices for the entire pipeline route for the unmitigated and mitigated cases, respectively. Figures 4.3 through 4.7 (later in the report) present the Risk Assessment Matrices broken down by physiographic regions for both the unmitigated and mitigated cases.

4.2 Qualitative Risk Overview Methodology

4.2.1 Overview

Fundamental to any risk assessment methodology is the meaning of “risk” which is defined as “the possibility of loss”. This concept of risk embodies two components: an uncertain state of knowledge about the occurrence of an event and adverse effects produced by the event should it occur. Expressed more simply:

Risk of hazard = Likelihood of occurrence of hazard
x Consequences of hazard

Consequently, in order to characterize risk appropriately, both the relative likelihood of a failure event (hazard) and its associated consequence(s) must be accounted for. During the qualitative identification and assessments undertaken for this report, the likelihood (probability) and consequences were evaluated using professional judgment and opinion based on available information including:

1. Information from aerial and ground reconnaissances during pipeline routing studies and studies of crossings.

2. Airphoto interpretation carried out by AMEC and terrain typing carried out by GEM.
3. Where available, LiDAR hill shade and slope shade models, orthomosaics and other photography.
4. Published information.
5. Other information available to AMEC from previous work in various areas along the proposed route.

4.2.2 Hazards

Terrain hazards have been evaluated during the course of routing and preliminary design work undertaken along the route. The terrain hazard categories identified were discussed above in Section 3.2.

4.2.3 Hazard Probabilities

Hazard probability categories varying from 1 (lowest likelihood) to 5 (highest likelihood) have been established for the purpose of rating the likelihood or probability of a hazard event occurring and affecting the pipelines. It should be noted that the rating is with respect to the likelihood of pipeline or facility damage. This may be different in some cases than the likelihood of an event such as rockfall occurring. Specifically, for a rockfall event to damage the pipelines, direct impact on the pipelines by a large block, possibly of a particular shape, would be required. Depending upon the characteristics of the event, the likelihood of direct impact on the pipelines may be much lower than the likelihood of rockfall occurring in the general area and/or bouncing across the pipelines without damaging them.

The hazards were assessed with respect to the 1 km wide corridor that contains the Rev R alignment. Thus, if an identified Terrain Hazard was present within the 1 km corridor, it was assessed in the analysis in this report. Hazards located outside the 1 km corridor, many of which were avoided during the routing work, are not included in the Risk Analysis.

For this study, a numerical rating was used in order that preliminary risk ratings could be provided by multiplying the Likelihood Category by the Consequence Rating discussed below. (Recall that *Risk= Likelihood X Consequence*). Table 4.1 provides the Hazard Likelihood Categories used in this study. As indicated later in the report, Hazard Likelihood (probability) Categories were assessed both without and with mitigation in place.

When considering the Hazard Likelihood Categories, it may be useful to recall that for the purpose of design earthquake assessments, a 1:2475 year earthquake is used as the design basis under the National Building Code of Canada for seismic assessments under the code. A 1:2475 year event is the same as a 2% likelihood of occurrence over a 50 year design life or an annual likelihood of occurrence of 0.0004 (Hazard Likelihood Category 1 in Table 4.1). Thus, while Hazard Likelihood Category 1 has a very low annual likelihood of occurrence, such *likelihoods are often taken into account during design and operation of major projects and structures, particularly when the event could have high consequences and/or the service life is considerably in excess of one year.

Table 4.1 Hazard Likelihood Categories (Hazard Occurrence Likelihoods)

Likelihood Category	Approximate Annual Likelihood	DESCRIPTION
5	≥ 0.5	*Will likely happen regularly over the life of the Project.* Very high likelihood that the hazard could affect the pipelines and/or infrastructure in the near future and/or is affecting the pipelines at the time of study.
4	≥ 0.1	*Probably will happen over the life of the Project.* High likelihood of occurrence.
3	≥ 0.1 to 0.02	*It could happen (likely as not) over the life of the Project.* Intermediate likelihood of occurrence.
2	< 0.02	*Unlikely to happen in any given year and less likely over the life of the Project.* Low likelihood.
1	< 0.001	Very low annual likelihood of occurrence and much less likely to occur over the life of the Project. Longer term events such as major seismic events.

4.2.4 Consequences

Similar to the Likelihood Categories, the Consequence Categories were also rated numerically from 1 to 5 (see Table 4.2). (Recall that Consequence is a measure of the adverse effects or outcomes of a Hazard that occurs and affects the pipelines or infrastructure).

Table 4.2 Consequence Categories

CONSEQUENCE CATEGORY	DESCRIPTION
5	***Major event with extremely costly and difficult remediation*** Pipeline failure or failure of major facilities such as pumping stations that could be difficult or expensive to repair due to location or other reasons.
4	***Significant event that can be addressed but with great effort*** All other major pipeline damage events requiring replacement of pipeline segment. Failure of other infrastructure such as pumping stations that would directly affect the ability to move oil.
3	***Moderate event requiring mitigation and certainly engineering review/input*** Displacement, damage or exposure of the pipelines less likely to directly result in immediate failure (i.e., in the event of the hazard occurring, there may be sufficient time to undertake mitigative measures prior to more serious consequences). Includes in-stream exposures. Damage to pumping stations or other facilities that does not immediately cause major shutdown.
2	***Minor incident or inefficiency that may require engineering review but is easily and predictably remediated*** Coating damage, exposure or other damage not immediately resulting in a serious situation. Overland locations. Relatively easy to repair.
1	***Minor incident or inefficiency of little or no consequence*** Other low consequence outcomes. (Note that failure to suitably mitigate these outcomes could result in more serious consequences.)

4.2.5 Risk Evaluation

The product of the two ratings (Hazard x Consequence) provides a preliminary measure of the geotechnical risk posed by the various geotechnical hazards identified. The likelihood and consequence rating categories were set with 5 as a high rating so that the maximum risk value (25) would apply to what are perceived as the geotechnical situations with the highest risk (highest likelihood and highest consequence) with respect to the pipelines and related infrastructure.

This measure of risk should be viewed as a numerical ranking only. There were several limitations to the work that affect the evaluation of the risk, as discussed below.

4.2.6 Limitations of the Risk Assessment

The following limitations apply to the risk evaluations discussed in this report:

1. A linear numerical progression has been used for the Consequence Categories as part of the qualitative assessment discussed in this report. However, there is no reason that the consequences should progress in a linear fashion. In fact, it is more likely that the greater consequences may be nonlinear, which would affect the overall risk ratings (product of likelihood and consequence).

2. A similar argument could also be applied to the Hazard Likelihood Categories. If the various likelihoods assigned to the different categories were reviewed in statistical detail, it might be found that the likelihood categories are also non-linear with respect to the actual numerical values of likelihood. Probability theory for natural events tends to support lognormal distributions and/or normal distributions for many of these events. However, the use of a linear approximation in the range of relatively common events is considered reasonable as a first approach for the Risk Assessments in this report.

3. Considering Points 1 and 2, a very likely event (Hazard Likelihood Category of 5) and a low Consequence Category (Consequence Category of 1) would have an overall Risk measure of 5. A similar numerical evaluation of Risk would be provided for a very unlikely event (Hazard Likelihood Category of 1) combined with a high Consequence Category of 5. However, in a more detailed risk evaluation, they might not be equal due to the non-linearity of both input categories.

4. The evaluations were made for both the unmitigated original condition and for the same hazards after mitigation. The evaluations assume that best practice engineering, design and operational methods will be employed. The assumptions included pipeline patrols, repair and maintenance work and pro-active mitigation where required.

5. Evaluations were made on the basis of office studies of existing information as discussed above. As recommended in Table B-1, additional investigations are anticipated during detailed design in several areas. As this further work is done, the preliminary Risk Assessments discussed may change.

6. The Consequence assessments were based mainly on geotechnical issues and natural terrain hazards. Other considerations could apply including other consequences (such as for neighbouring pipelines) in more detailed overall Risk assessments for the purpose of pipeline integrity studies.

7. Other geotechnically related issues such as sediment generation will need to be considered during design, construction and operation. These issues have not been considered in detail for all areas; however, additional preliminary recommendations pertaining to sedimentation issues are contained in Section 5 and discussed in Table B-1.

8. Most Hazard events of low consequence have not been included directly in the Risk study.

Combined events where progressive failures could occur were not assessed as hazards but were evaluated as isolated occurrences.

4.3 Results of Risk Analysis

The results of the Risk Analysis are summarized graphically on Figures 4.1 to 4.7. These figures show matrices in which Hazard Likelihood is plotted on the X axis and Consequence is plotted on the Y axis. The grey lines running diagonally across the cells and the cell shading indicate zones of roughly equal Risk (Risk = Hazard x Consequences). Within each cell, the number of occurrences of different Terrain Hazard categories and the type of category are listed (bracketed numbers on Figures 4.1 and 4.2). The type of Hazard is indicated by the two letter abbreviations. Numbers not in brackets (Figures 4.3 to 4.7) indicate the actual terrain hazard. The numbers are organized by Physiographic Region and refer to Table C-1 that provides a detailed breakdown of each Hazard discussed.

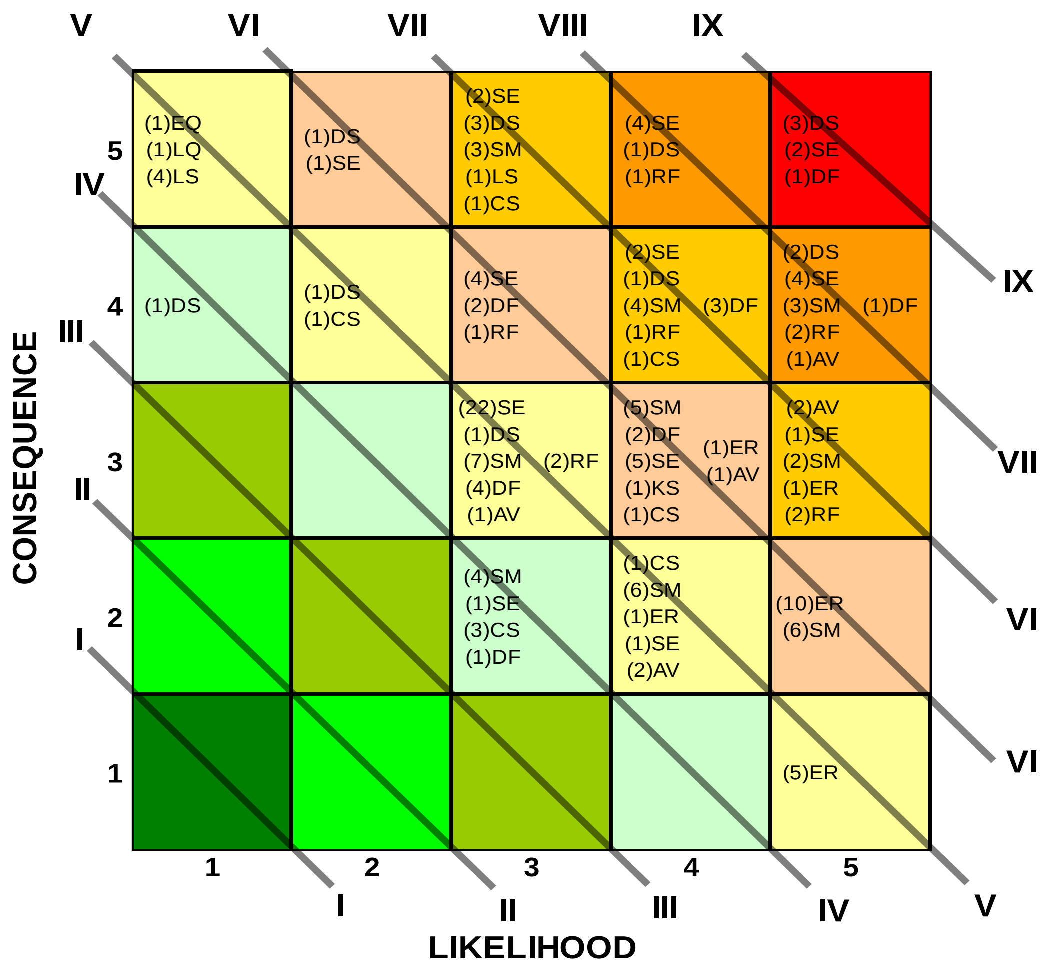
4.3.1 Overall Risks

Figures 4.1 (unmitigated risks) and 4.2 (mitigated risks) summarize the Terrain Hazard Risks for the entire pipeline route. Mitigation methods and additional details are discussed in Table C-1.

The unmitigated Risks shown on Figure 4.1 indicate a significant number of high Risks. As shown on Figure 4.2, mitigation results in significantly decreased risks. Three low to moderate risks remain in Risk categories IV and V.

Figures 4.3 to 4.7 show the risk matrices for the unmitigated and mitigated risks for the individual Physiographic Regions. The lists of risks indicate the site numbers (unbracketed number) that correspond to the sites in Table C-1. These matrices indicate that the remaining low to moderate risk sites after mitigation are at the Iosegun River (stream lateral erosion), and at the east and west approach slopes to the Little Smoky River. The results of the risk assessments may change during ongoing engineering and detailed design as well as a result of crossing method choices and design.

REV P RISK MATRIX SUMMARY (UNMITIGATED)



Mass Wasting

DS Deep-seated slides
SM Shallow to moderately deep slides
DF Debris Flow
RF Rock Fall
AV Avalanches
LS Lateral Spreading
SE Stream Erosion & sedimentation
ER Wind & shallow stream or overland erosion

Settlement

CS Consolidation Settlement
KS Karst induced Settlement or displacement

Seismic

EQ Seismic Motion
LQ Liquefaction

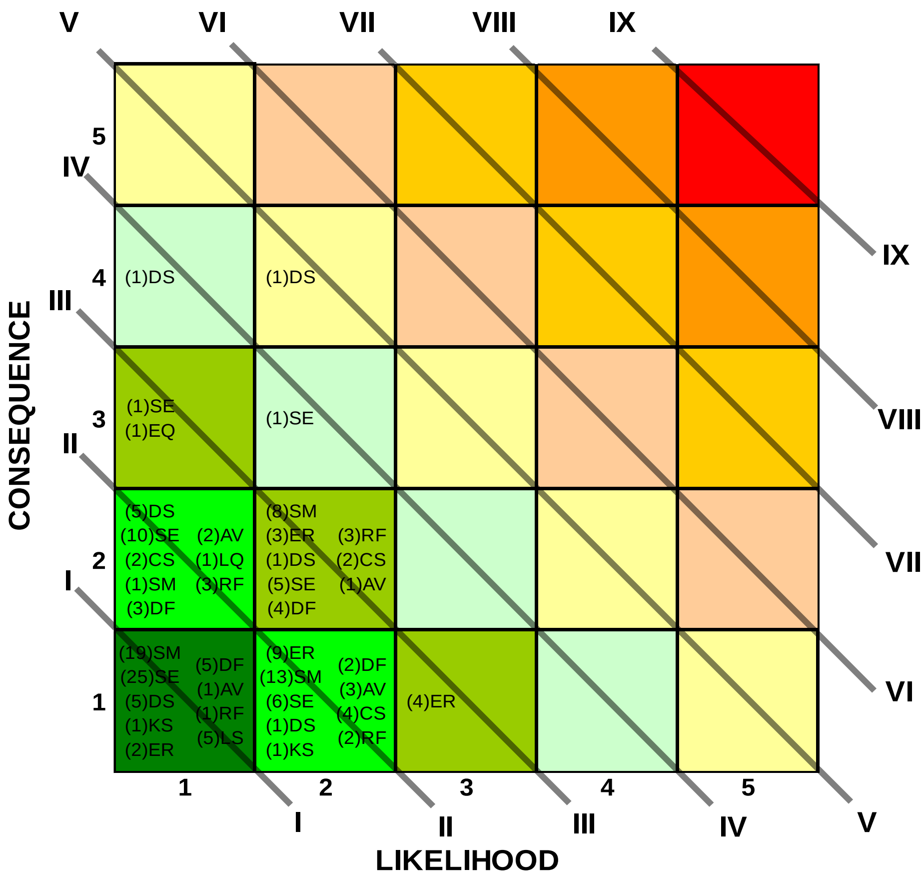
Tsunamis

TS Tsunamis

(#) Number of occurances of Geohazard that fit in that square of the Risk Matrix

Figure 4.1 Unmitigated Risk Matrix Summary

REV P RISK MATRIX SUMMARY (MITIGATED)



Mass Wasting

DS Deep-seated slides
SM Shallow to moderately deep slides
DF Debris Flow
RF Rock Fall
AV Avalanches
LS Lateral Spreading
SE Stream Erosion & sedimentation
ER Wind & shallow stream or overland erosion

Settlement

CS Consolidation Settlement
KS Karst induced Settlement or displacement

Seismic

EQ Seismic Motion
LQ Liquefaction

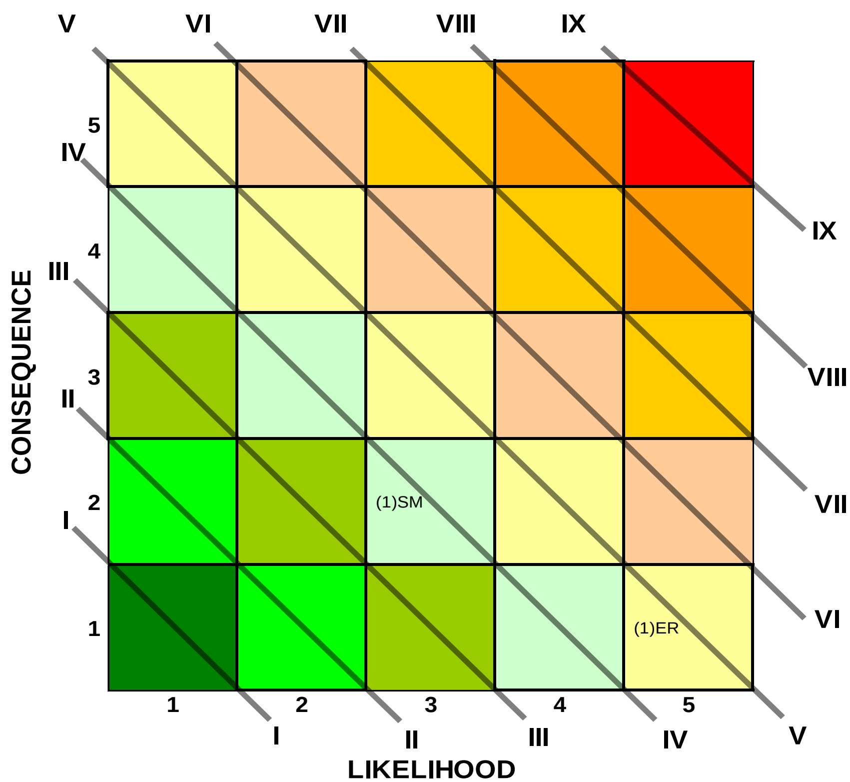
Tsunamis

TS Tsunamis

(#) Number of occurances of Geohazard that fit in that square of the Risk Matrix

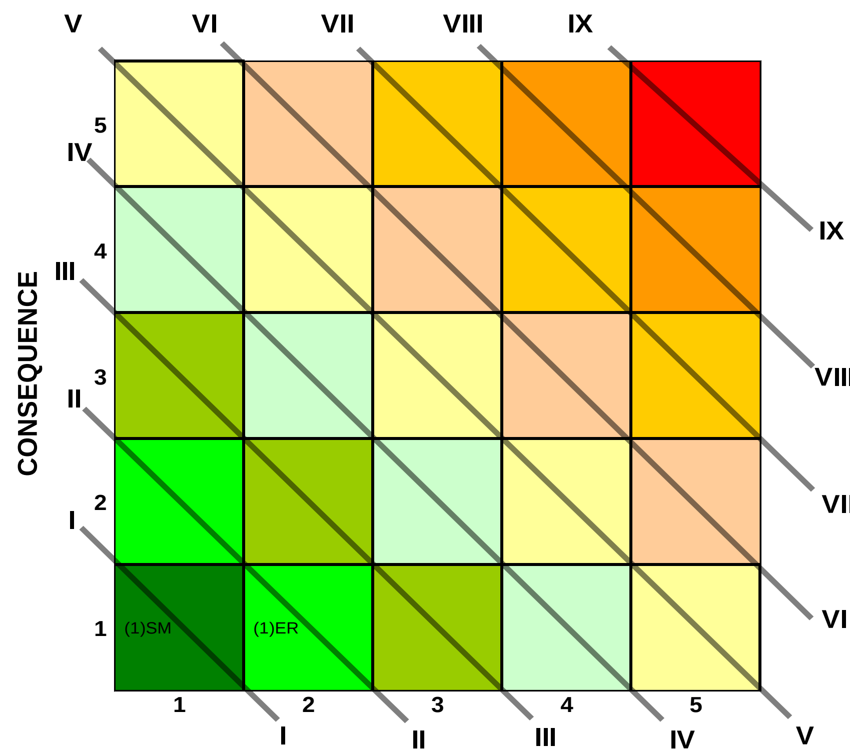
Figure 4.2 Mitigated Risk Matrix Summary

EASTERN ALBERTA PLAINS RISK MATRIX SUMMARY (UNMITIGATED)



RISK CLASS	GEOHAZARD CODE
I	
II	
III	
IV	2SM
V	1ER
VI	
VII	
VIII	
IX	

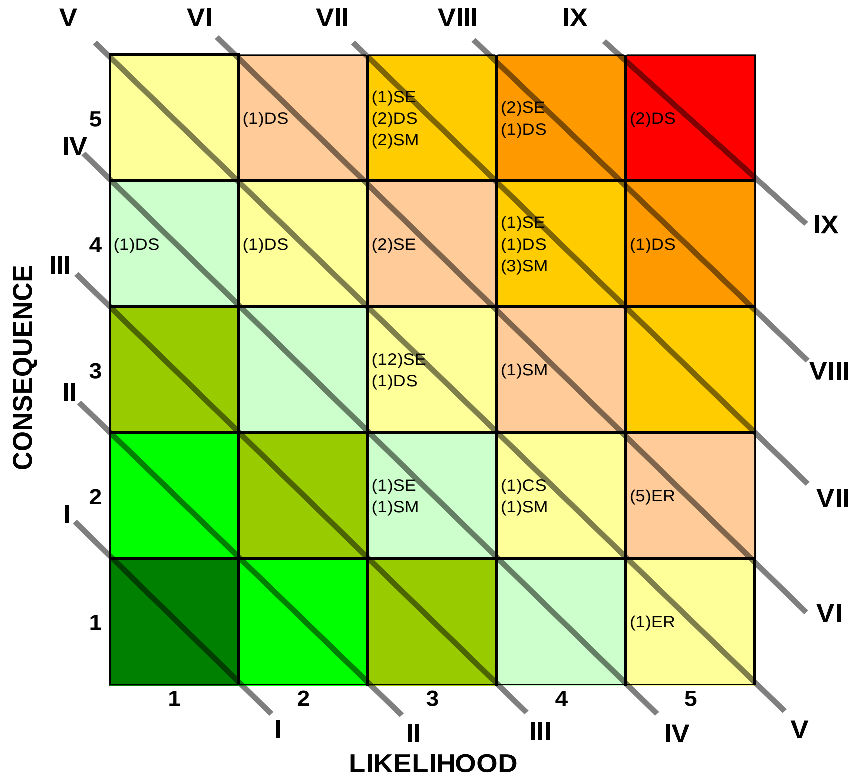
EASTERN ALBERTA PLAINS RISK MATRIX SUMMARY (MITIGATED)



RISK CLASS	GEOHAZARD CODE
I	2SM
II	1ER
III	
IV	
V	
VI	
VII	
VIII	
IX	

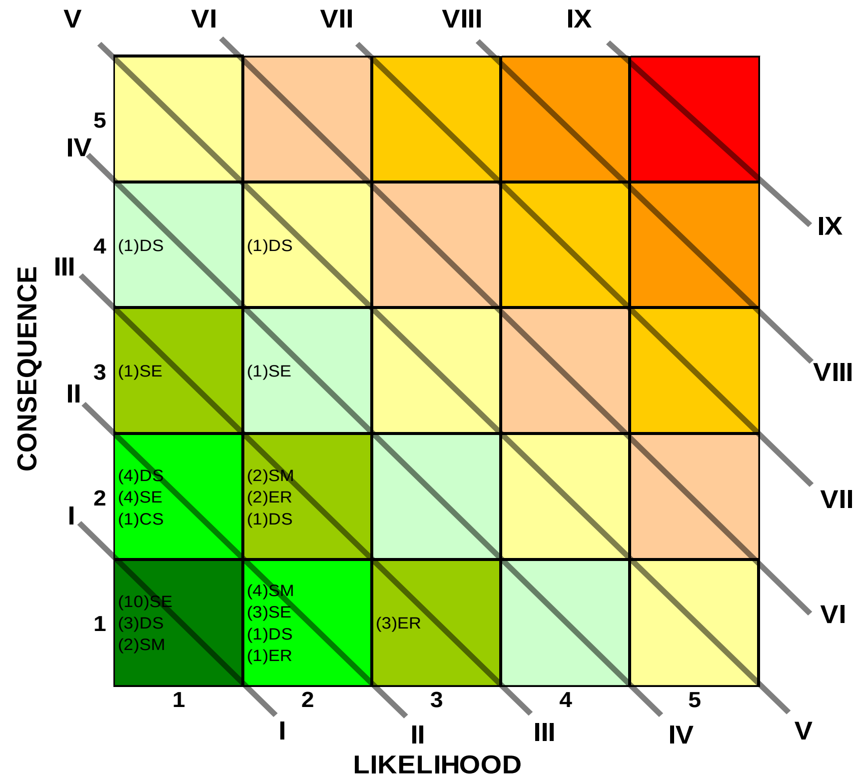
Figure 4.3 Eastern Alberta Plains Risk Assessment Matrices

SOUTHERN ALBERTA UPLANDS RISK MATRIX SUMMARY (UNMITIGATED)



RISK CLASS	GEOHAZARD CODE
I	
II	
III	5DS
IV	12SM, 41SE
V	3SE, 4SE, 10SE, 13SE, 14SE, 16ER, 17SE, 18CS, 23SE, 24SE, 28DS, 29SE, 31SE, 32SM, 38SE, 43SE, 47DS
VI	7SE, 8SM, 19DS, 25ER, 26ER, 27SE, 37ER, 40ER, 44ER
VII	6SE, 9DS, 11SM, 15SM, 21DS, 22SE, 35DS, 36SM, 39SM, 42SM
VIII	20SE, 30DS, 34SE, 46DS
IX	33DS, 45DS

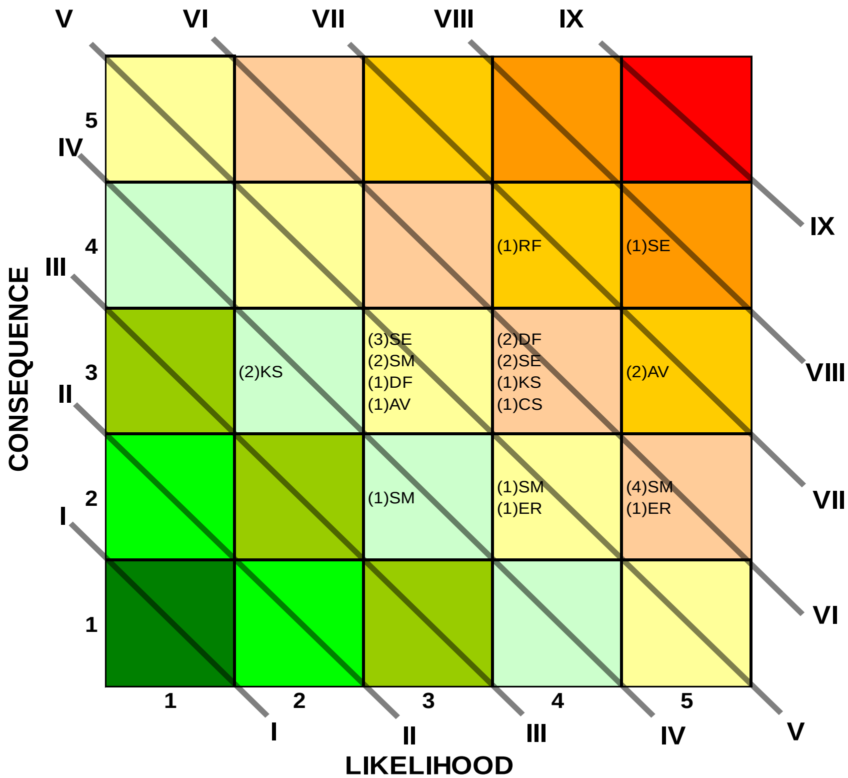
SOUTHERN ALBERTA UPLANDS RISK MATRIX SUMMARY (MITIGATED)



RISK CLASS	GEOHAZARD CODE
I	3SE, 4SE, 6SE, 9DS, 10SE, 12SM, 15SM, 22SE, 23SE, 29SE, 30SE, 34SE, 41SE, 43SE, 45DS
II	5DS, 7SE, 8SM, 13SE, 14SE, 16ER, 18CS, 24SE, 27SE, 28DS, 31SE, 32SM, 33DS, 36SM, 38SE, 42SM, 46DS, 47DS
III	11SM, 20SE, 25ER, 26ER, 35DS, 37SM, 39SM, 40ER, 44ER
IV	17SE, 19DS
V	21DS
VI	
VII	
VIII	
IX	

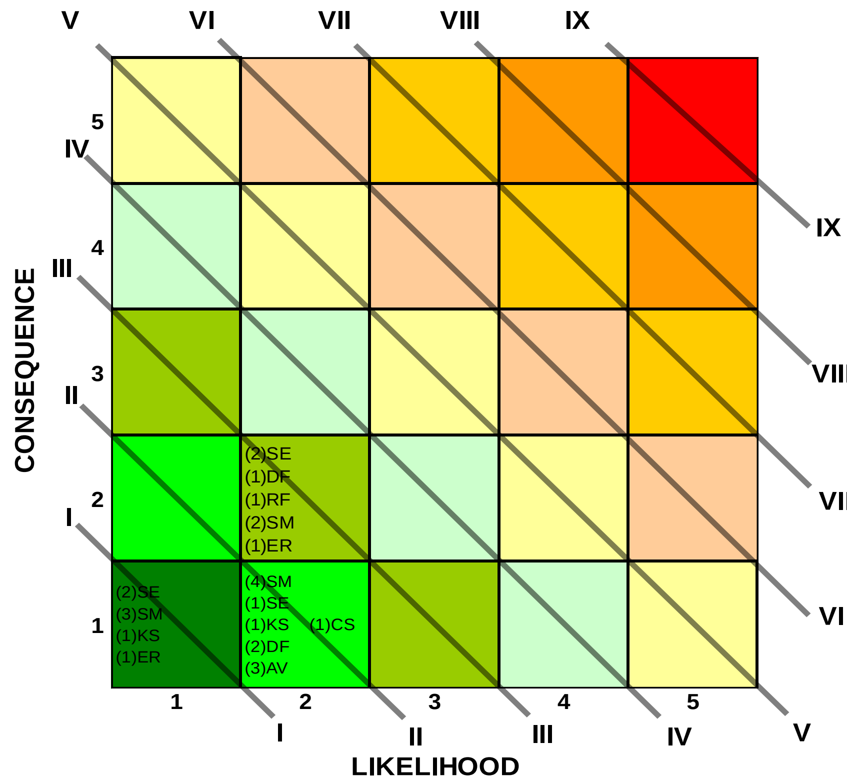
Figure 4.4 Southern Alberta Uplands Risk Assessment Matrices

ROCKY MOUNTAINS RISK MATRIX SUMMARY (UNMITIGATED)



RISK CLASS	GEOHAZARD CODE
I	
II	
III	
IV	49SM, 55KS, 61KS
V	49SE, 51SE, 53SE, 54SM, 56SM, 64SM, 69DF, 71AV, 74ER
VI	50DF, 57SE, 58DF, 60SM, 65KS, 66CS, 67ER, 68SE, 70SM, 72SM, 73SM
VII	59AV, 62 AV, 63RF
VIII	52SE
IX	

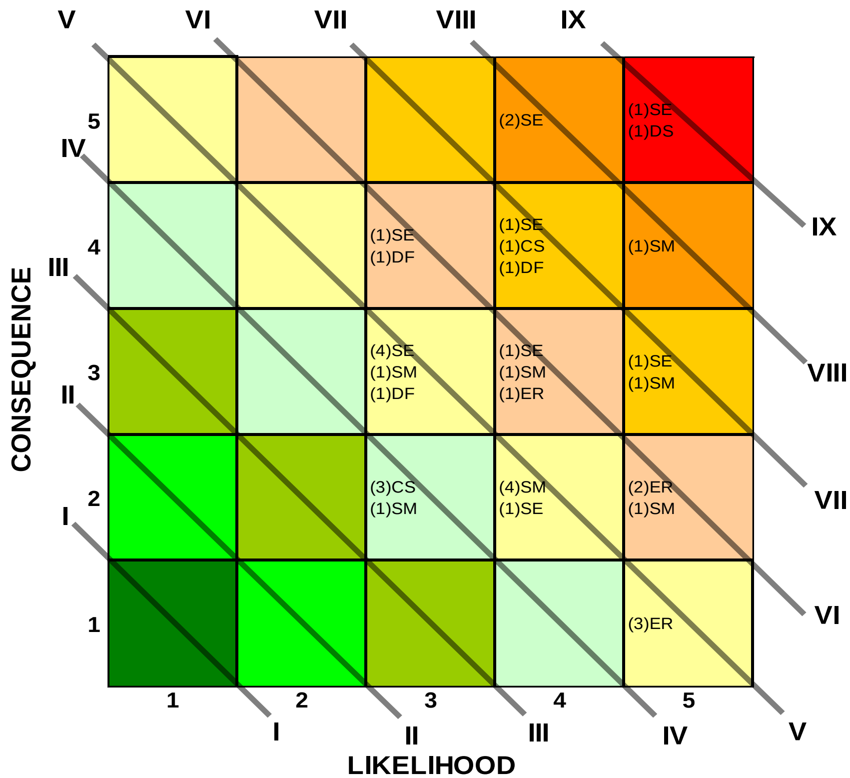
ROCKY MOUNTAINS RISK MATRIX SUMMARY (MITIGATED)



RISK CLASS	GEOHAZARD CODE
I	51SE, 53SE, 60SM, 61KS, 64SM, 65KS, 67ER
II	48SM, 49SE, 54SM, 55KS, 56SM, 58DF, 59AV, 62AV, 66CS, 68SE, 69DF, 71AV, 73SM
III	50DF, 52SE, 57SE, 63RF, 70SM, 72SM, 74ER
IV	
V	
VI	
VII	
VIII	
IX	

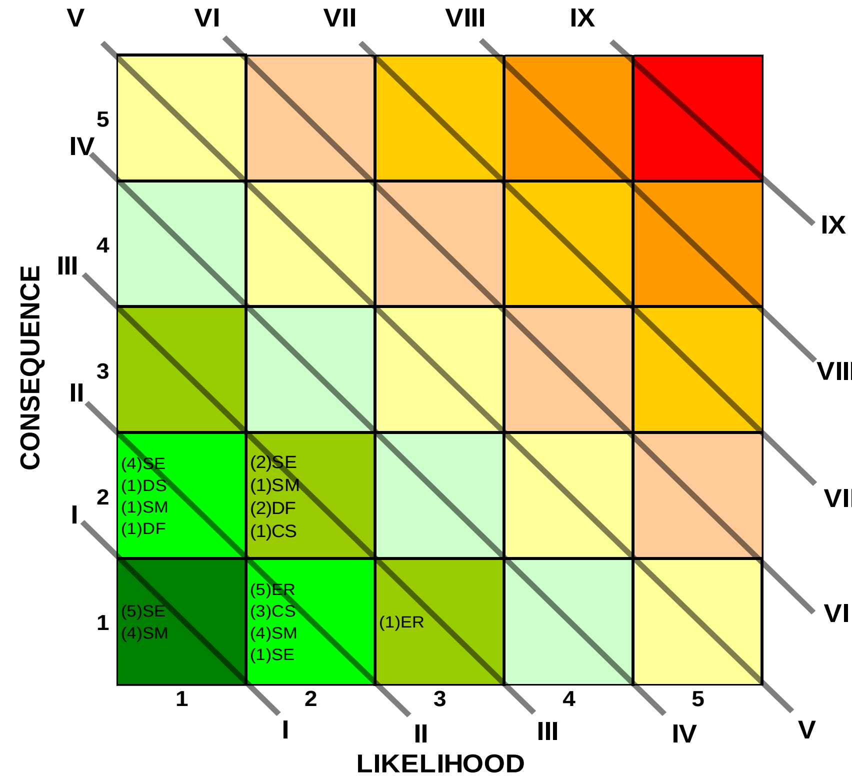
Figure 4.5 Rocky Mountains Risk Assessment Matrices

INTERIOR PLATEAU RISK MATRIX SUMMARY (UNMITIGATED)



RISK CLASS	GEOHAZARD CODE
I	
II	
III	
IV	76CS, 88CS, 89CS, 101SM
V	75SM, 78SM, 79SE, 80ER, 81SM, 82SE, 83ER, 85ER, 92SM, 102SE, 103SM, 108SE, 109SE, 110DF
VI	84SM, 87SE, 90SE, 93ER, 98SM, 99ER, 104ER, 107DF
VII	86SE, 96CS, 97SE, 100SM, 106DF
VIII	77SE, 95SM, 105SE
IX	91SE, 94DS

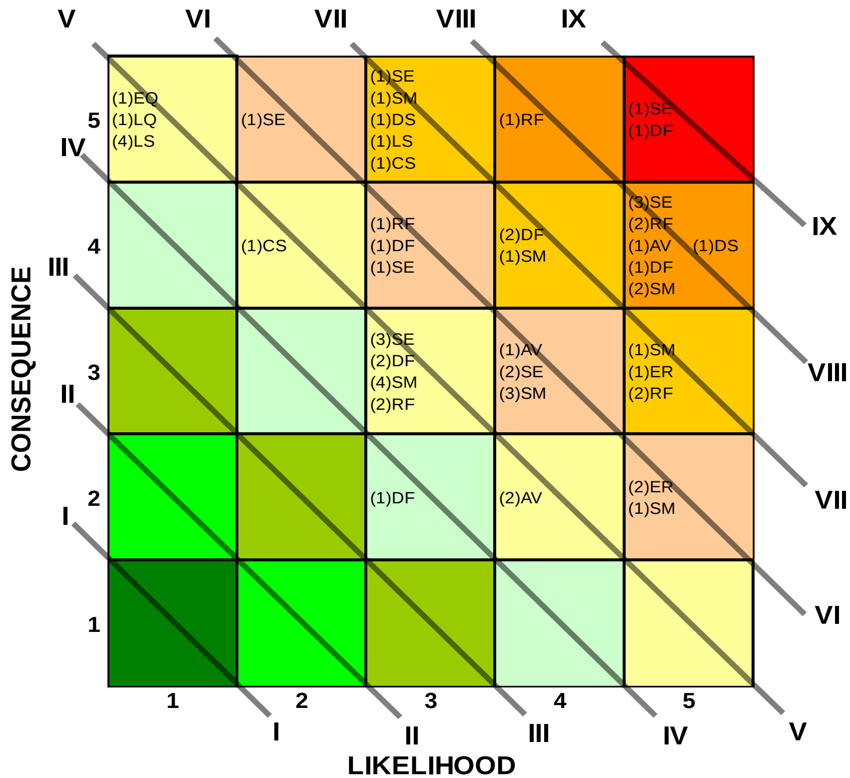
INTERIOR PLATEAU RISK MATRIX SUMMARY (MITIGATED)



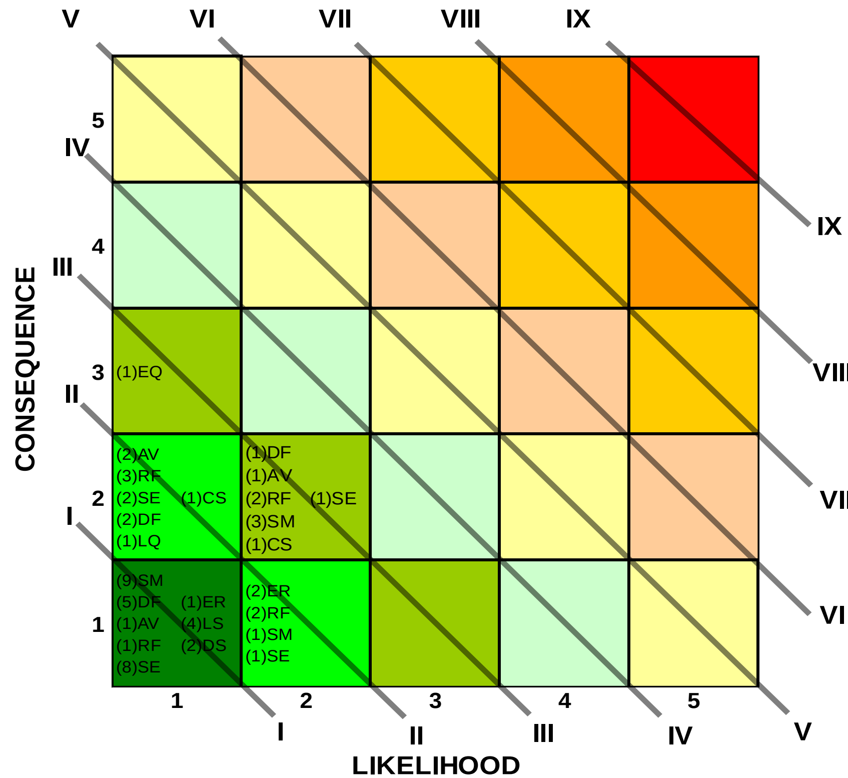
RISK CLASS	GEOHAZARD CODE
I	75SM, 77SE, 82SE, 87SE, 95SM, 98SM, 101SM, 102SE, 108SE
II	76CS, 78SM, 79SE, 80ER, 81SM, 83ER, 84SM, 86SE, 88CS, 89CS, 90SE, 92SM, 93ER, 97SE, 99ER, 100SM, 104ER, 109SE, 110DF
III	85ER, 91SE, 96CS, 103SM, 105SE, 106DF, 107DF
IV	
V	
VI	
VII	
VIII	
IX	

Figure 4.6 Interior Plateau Risk Assessment Matrices

COAST MOUNTAINS RISK MATRIX SUMMARY (UNMITIGATED)



COAST MOUNTAINS RISK MATRIX SUMMARY (MITIGATED)



RISK CLASS	GEOHAZARD CODE
I	
II	
III	
IV	116DF
V	111EQ, 117AV, 119AV, 122RF, 133SE, 142LS, 143SM, 146SM, 147LS, 148LS, 149SM, 152LS, 153SM, 154SE, 158LQ, 159DF, 163SE, 168CS, 169DF, 170RF
VI	112SM, 113ER, 115SM, 120RF, 123SE, 124SM, 128SM, 129SE, 130DF, 132AV, 138ER, 151SE, 156SE
VII	121DF, 131SM, 140ER, 141RF, 144RF, 155SE, 157CS, 160SM, 162DF, 165SM, 166DS, 167CS
VIII	114SE, 118RF, 125AV, 134DF, 135RF, 136SE, 137SE, 139SM, 145DS, 150SM, 161RF
IX	126SE, 127DF

RISK CLASS	GEOHAZARD CODE
I	112SM, 114SE, 115SM, 116DF, 119AV, 120RF, 123SE, 124SM, 126SE, 127DF, 128SM, 136SE, 139SM, 140ER, 142LS, 143SM, , 145DS, 147LS, 148LS, 149SM, 150SM, 151SE, 152LS, 153SM, 154SE, 156SE, 159DF, 162DF, 163SE, 166DS, 167LS, 169DF
II	113ER, 117AV, 118RF, 122RF, 125AV, 129SE, 130DF, 131SM, 133SE, 134DF, 135RF, 137SE, 138ER, 144RF, 158LQ, 168CS, 170RF
III	111EQ, 121DF, 132AV, 141RF, 146SM, 155SE, 157CS, 160SM, 161RF, 165SM
IV	
V	
VI	

Figure 4.7 Coast Mountains Risk Assessment Matrices

5.0 GENERAL GEOTECHNICAL RECOMMENDATIONS

5.1 General

This section provides preliminary geotechnical recommendations pertaining to issues that will occur across many parts of the route. They are provided to indicate some of the important geotechnical issues and preliminary mitigative methods that will be expanded upon during detailed design phases of the Project. The recommendations presented below are not considered to be final and are expected to be developed and refined during detailed design phases of the project and during construction. Similarly, detailed drawings and specifications which will outline detailed design and installation issues are also expected to be developed during detailed design. During construction, geotechnical input is recommended to refine the general geotechnical recommendations.

Along some areas of the route, it is anticipated that detailed engineering design will be required that will be more detailed than often used on pipeline projects (for example, parts of the upper Kitimat Valley). Also, detailed designs for high rock or soil cuts will require specific geotechnical input. These detailed designs are outside the scope of the more general preliminary recommendations presented below. Recommendations in Table B-1 provide additional information on preliminary recommendations and areas where detailed design may be required.

5.2 Grading

5.2.1 General

1. As recommended below, with a few exceptions, clay or silt fills should generally not be placed back on the right-of-way to depths greater than 0.3 m where longitudinal slopes along the right-of-way exceed approximately 11° (5H:1V) without additional geotechnical input that will likely include recommendations for compaction. Sand fills should not be placed to depths greater than 0.3 m on longitudinal slopes greater than 14° (4H:1V) without geotechnical input, which may include recommendations for compaction. Shot rock fills should not be placed back on graded longitudinal slopes greater than 32° (1.6H:1V). These recommendations are made since excessive depths of material placed on a portion of the grade running downhill at angles steeper than those noted will have an increased tendency to slide.

2. Where the foregoing recommendations would be exceeded, additional geotechnical input is recommended. Mitigative measures may include disposing of cut materials along the right-of-way at another suitable location or planning a deeper cut at a lower longitudinal slope. Additional workspace may be required in some cases.

3. Steep slopes where the sidecuts will exceed approximately 6 m high may require specific geotechnical input. The higher cuts may also require additional workspace to provide sufficient working room for the cut and fill slopes.

4. The pipelines should, in general, be installed in native ground. Pipelines should not be placed in fill without specific geotechnical recommendations.

5. During detailed design and construction, it is anticipated that further geotechnical review and input will be provided on cut and fill slopes as well as the general grading plans in order to reduce the potential for inducing stability or siltation problems.

5.2.2 Cuts

The following preliminary recommendations are made for soil cuts up to 6 m high that do not undercut (oversteepen) existing overall slopes:

1. Cuts in sideslopes extending upslope from the crest of the cut more than 10 m at angles of 25° or more should be examined from a geotechnical point-of-view. The specific concern is to avoid creating ravelling failures in overburden that may retrogress far upslope above the grade cut.

2. Cuts should be as shallow as possible while providing the required grade and working room. Excessively deep cuts will generate higher than optimal cut slopes which may be subject to stability considerations. In addition, as discussed above, significant quantities of cut materials should not be placed back on approach slopes to streams and so disposal areas will be required for these cut materials. If the cuts are kept as low as possible, then disposal problems will be reduced.

3. Short term cuts in soil may be made at angles up to 36.9° (1H to 3/4V) to heights of 1.5 to 6 m subject to Workers Compensation Board requirements. However, these cuts will undergo shallow failure with time and long term cut angles of 26.5° (2H:1V) are recommended for most soil cuts.

4. Rock cuts up to 6 m high should typically be blasted with vertical slopes except where otherwise identified. Final cut slopes after scaling will have variable, but flatter angles. Cuts more than 3 m high should typically be blasted using presplit or other “smooth wall” techniques. Scaling will be required.

5. If seepage is observed or suspected, the area should be reviewed geotechnically in case additional measures to reduce erosion and siltation are required. These measures might include groundwater drainage or rock blankets; however, individual requirements will vary. This recommendation particularly applies to seepage in sandy materials which may initiate groundwater piping (internal erosion) which can rapidly retrogress upslope, and which may be difficult and expensive to repair if allowed to get out of control.

6. Stockpiles or sources of shotrock or free draining gravel and medium to heavy weight non-woven geotextile should be available at various locations in all physiographic regions west of the Eastern Alberta Plains. In emergency situations, where groundwater piping is occurring, the geotextile should be placed over the seepage area and 0.5 to 1 m (depending on flow volumes) of free draining gravel or shotrock placed over the area. Additional geotechnical input should be sought. It is noted that rock or gravel blankets placed on slopes will require toe support or they will tend to slide downslope.

5.2.3 Fills

The following recommendations pertain to fills placed during grading:

1. Fill slopes should generally be constructed at inclinations of 26.5° (2H:1V) for clay and silt rich materials. Sand and gravel may be placed to angles of 36° on a temporary basis. Strong shot rock may be placed to angles of 38°. Fill heights should be limited to 3 m without additional geotechnical input.

2. Weak rock containing high plastic clay materials (eg, some shale, bentonitic sandstone, bentonitic mudstone) are undesirable for long-term fills because the shale may break down to form soft cohesive soils. They also drain poorly and instability can result from this poor drainage. Where clay rich materials are used for fill more than 2 deep, fill slope angles should be reduced form those in Point 1 to take account of the lower shear strength of the material with time. Geotechnical input should be provided for higher or steeper fills of weak rock.

3. Snow and ice should not be incorporated into fills or left under fills. Frozen soils should not be used for permanent fills unless the potential for future sliding or erosion will not progress off the RoW and is acceptable in the particular circumstances.

4. Ground surface preparation in areas where fill slopes will be placed should include removal of snow accumulations, fallen logs and stumps, and stripping of surficial organic soils to the rooting depth. Ice rich soils should be removed. Fills should not be retained by trees, logs or other similar means.

5. Material used for fill should consist of mineral soil or shotrock and should be as dry as possible. Placement of snow or ice-rich soils, large frozen lumps, or wet materials should be avoided or specific geotechnical advice should be obtained. Snow and ice rich surficial soils should be removed from areas where fill will be placed and from borrow areas prior to excavation.

6. If fills are placed across areas of seepage (either ephemeral or permanent), subdrainage such as Multi Flow™ prefabricated drains or French drains should be installed. French drains should be used where there are large volumes of seepage. Multi Flow™ drains are suitable to drain lower volume seepages (up to 2 l/min). Drains should be placed against undisturbed mineral soil.

7. As a minimum, fill should be compacted using track compaction by heavy equipment. Track compaction should not be used in settlement sensitive areas where engineered fills and specific compaction control may be required.

8. See recommendations above for maximum depths of fills on longitudinal slopes parallel to the pipelines. Locally deeper fills consisting of small fillets of material can be placed to stabilize steep cut slopes along the edge of the right-of-way. Such fills should generally conform to other recommendations in this report.

5.2.4 Surface and Ground Water Control

Surface and ground water control is an extremely important aspect affecting slope stability as well as sedimentation and erosion. Geotechnical input into surface and ground water control measures is recommended. The following preliminary general geotechnical recommendations are made:

1. The purpose of the surface and ground water control measures is to direct water off the right-of-way and out of the pipeline trenches in a controlled and planned manner with the aims of controlling erosion and the right-of-way grade and avoiding directly concentrated water flows into areas where these flows might be detrimental to stability, erosion or siltation.

2. Existing swales and draws should not be obstructed so that runoff water becomes diverted along the RoW grade or ponded behind fill. Cross berms should be used to maintain surface water flows in the same locations as prior to construction. The aim is for the RoW grade to have a minimal impact on surface water conditions.

3. Where there are adjacent rights-of-ways, surface water control will need to be planned in conjunction with the measures in place on the adjacent areas.

4. Roll back should not be done on slopes. Roll back consists of organic debris and surficial organic soils that are sometimes placed back on the pipeline right-of-way. On slopes, roll back has been found to significantly increase the amount of infiltration and to impede water runoff resulting in decreased stability. Where disposal of organic rich material is required, this material should be moved to flat areas beyond the crest or toe of the slope.

The following recommendations are made with respect to cross berms:

1. Cross berms should be placed at frequent intervals down the slopes to direct water off the right-of-way. Cross berms should also be placed immediately downstream of all trench blocks to direct water off the RoW that is forced to the surface by the trench block.

2. Final locations and flow directions of cross berms should be chosen in the field with geotechnical input. It is most important that surface water should not be directed into tension cracks or other areas prone to stability issues.

3. Cross berms should consist of compacted unfrozen mineral soil in a berm up to 0.5 m high running diagonally across the RoW. The slope along the berm should preferably be about 10%. The use of higher berms is usually not required and is generally not an advantage except for access control.

4. Shallow swales on the uphill side can be used to augment cross berms.

5. In case of erodible soils, consideration can be given to lining the swale on the uphill side of the berm with an erosion mat.

Trench blocks should be installed in the pipeline trenches at intervals as required to control and interrupt water flow along the trench. The purposes are to reduce internal erosion of soil and padding along the trench and to avoid transporting water along the trench from upland areas into areas of sensitive slopes or slides.

1. Trench blocks should be located at intervals down the slope including below seepage areas or drainage swales.

2. Compacted clay trench blocks are generally preferred geotechnically over other types of trench blocks such as sand bag or foam blocks. Clean native soil materials and bentonite (eg, prebagged drilling mud) compacted into place should preferably be used to form the blocks. No organics, topsoil, sticks, other non-soil materials or garbage should be present in the soil used.

3. Sandbag trench blocks are typically less preferable than either clay or foam types, but may be considered under special circumstances.

4. Foam trench blocks may be placed in areas where it is not possible to place clay trench blocks. The disadvantages of foam blocks include the tendency for foam blocks to shrink in the long term, and the inability of the block to reseal in the event of pipeline movement.

5. Where there may be appreciable water collection behind a trench block, drainage using Multi-Flow drains or French drains may be considered. Such drains should be directed downslope to areas where the flow will be directed off the RoW either by topography or by cross berms.

Drainage is required under fills that are placed over areas of seepage and may also be required to control springs on cuts, in the right-of-way grade or in the trench.

1. Multi-Flow™ drains consist of a series of small diameter perforated polyethylene pipes bonded together to form a sheet and covered with non-woven geotextile. The 18" wide drain is recommended in all cases. The drains are suitable for draining small to moderate seepage zones. Manifolds, elbows and solid wall pipe should be used in combination with the drains to route water off the RoW. Care should be taken to wrap the filter cloth around the uphill end of the installation to prevent soil ingress and fouling. Multi-Flow™ drains are recommended for installation in the following areas:

   - On the uphill sides of trench blocks where drainage of accumulated water is desirable.

   - In the bottoms of selected drainage ditches prone to sloughing. In these areas, the drain should be laid along the bottom of the ditch and either stapled to the bottom or weighted down with occasional cobbles. The purpose of the drains along the trenches is to allow water flow to continue in the event of surficial sloughing that blocks the ditch.

2. French drains: French drains consist of free draining gravel with a drain pipe encapsulated by non-woven geotextile and installed in a trench. French drains are used where high seepage flows occur.

3. Drainage blankets consist of clean shotrock fill placed to depths of approximately 1 m over geotextile on slopes. The purpose is to allow seepage to exit from cuts without creating erosion problems.

5.2.5 Clean-up and Revegetation

1. The RoW surface should be left in a condition that will shed water, particularly on approach slopes to streams and in areas prone to slides. Ruts, depressions and similar sources of increased water infiltration should be graded out or repaired to avoid increases in infiltration that could result in sliding.

2. All disturbed soil surfaces should be revegetated with a suitable seed mix. Multiple applications may be required to achieve an adequate vegetation catch.

3. Mulching and other measures may be required in some soils such as sand.

4. As noted elsewhere, the use of rollback is not recommended on slopes due to the increased likelihood of slope and erosion problems.

5. The RoW should be checked frequently during the first year to identify areas where additional work may be required to improve surface or ground water drainage, erosion, poor revegetation catch or stability problems.

6.0 LIMITATIONS AND CLOSURE

Recommendations and evaluations presented herein are based on preliminary data and are considered preliminary. In general, detailed on-ground site evaluations have not been done at many locations. It is expected that further investigations will be undertaken for the areas discussed in this report during detailed engineering for design and construction. Other more detailed reports have been prepared for some aspects of the project and these reports should be referenced as applicable. If conditions other than those reported are noted during subsequent phases of the project, AMEC Earth & Environmental should be notified and be given the opportunity to review and revise the current recommendations, if necessary.

This report has been prepared for the exclusive use of Northern Gateway Pipelines Inc. for specific application to the area within this report. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC Earth & Environmental accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. It has been prepared in accordance with generally accepted geotechnical engineering practices. No other warranty, expressed or implied, is made.

Respectfully submitted,

AMEC Earth & Environmental,
a division of AMEC Americas Limited

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PERMIT TO PRACTICE
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Date
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The Association of Professional Engineers, Geologists and Geophysicists of Alberta

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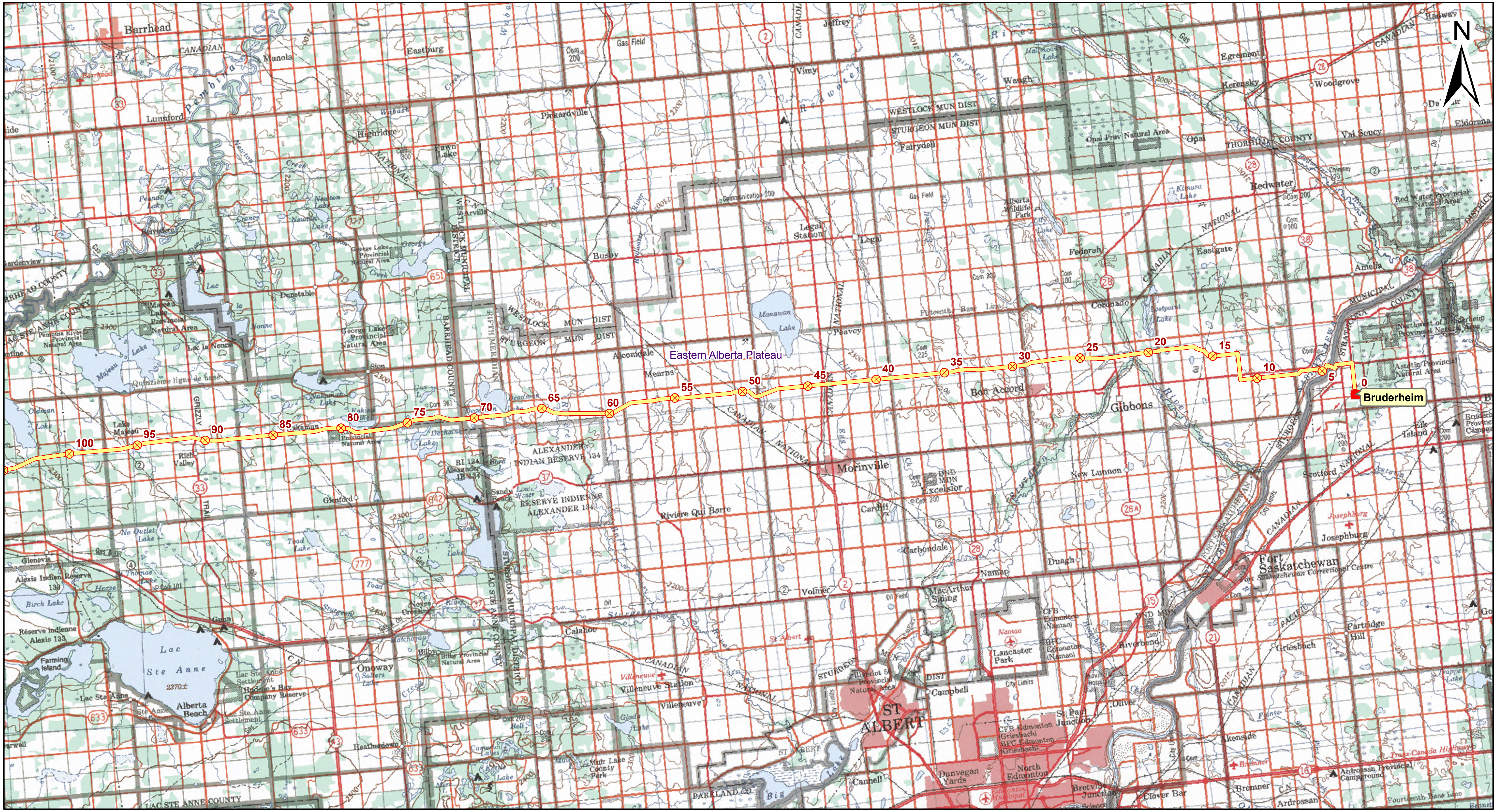
APPENDIX A

Route Location Figures A-1 to A-11



LEGEND

- Kilometre Post (July 27, 2009)
- Proposed Route (July 27, 2009)

Pump Station
- Condensate
- Condensate / Crude
- Crude
- Physiographic Boundary

SCALE: 1:275,000

0 2 4 6
Kilometers

PROJECTION: LCC

DATUM: NAD 83

ENBRIDGE NORTHERN GATEWAY PROJECT

Route Location
KP 0 - KP 100
Physiographic Boundaries

PROJECT NUMBER: EG0926008.3001

DATE: February 5, 2010

QA/QC: DC

REFERENCE: Pipeline Route: Rev. R. July 27, 2009

CONTRACTOR: AMEC Earth & Environmental

Figure A-1

ENBRIDGE NORTHERN GATEWAY PIPELINES

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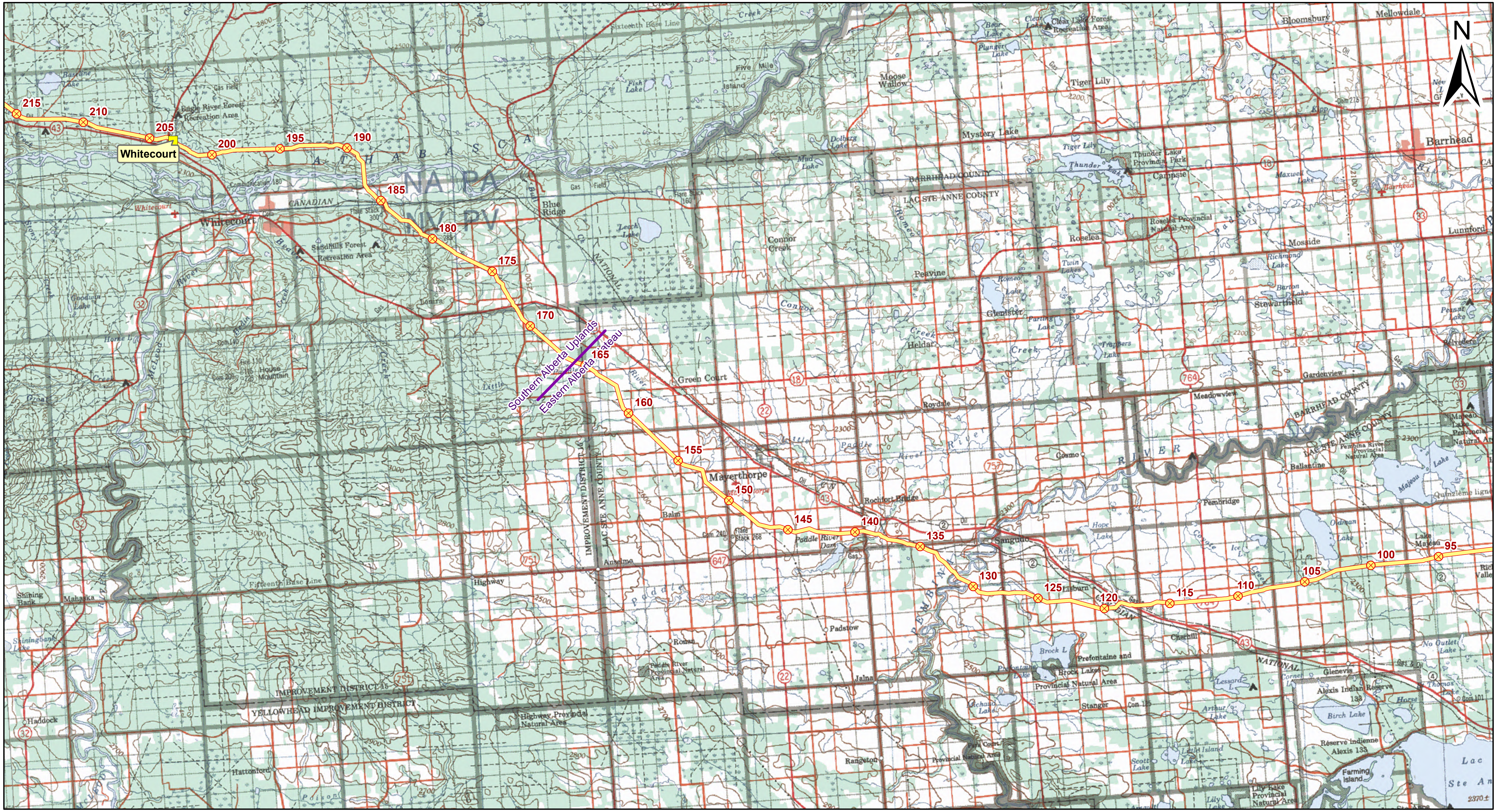

LEGEND

- Kilometre Post (July 27, 2009)
- Proposed Route (July 27, 2009)

Pump Station

- Condensate
- Condensate / Crude
- Crude
- Physiographic Boundary

ENBRIDGE NORTHERN GATEWAY PIPELINES

SCALE: 1:275,000

0 2 4 6

Kilometers

PROJECTION: LCC

DATUM: NAD 83

ENBRIDGE NORTHERN GATEWAY PROJECT

Route Location
KP 100 - KP 215
Physiographic Boundaries

PROJECT NUMBER: EG0926008.3001

DATE: February 5, 2010

QA/QC: DC

REFERENCE: Pipeline Route: Rev. R. July 27, 2009

CONTRACTOR: AMEC Earth & Environmental

Figure A-2

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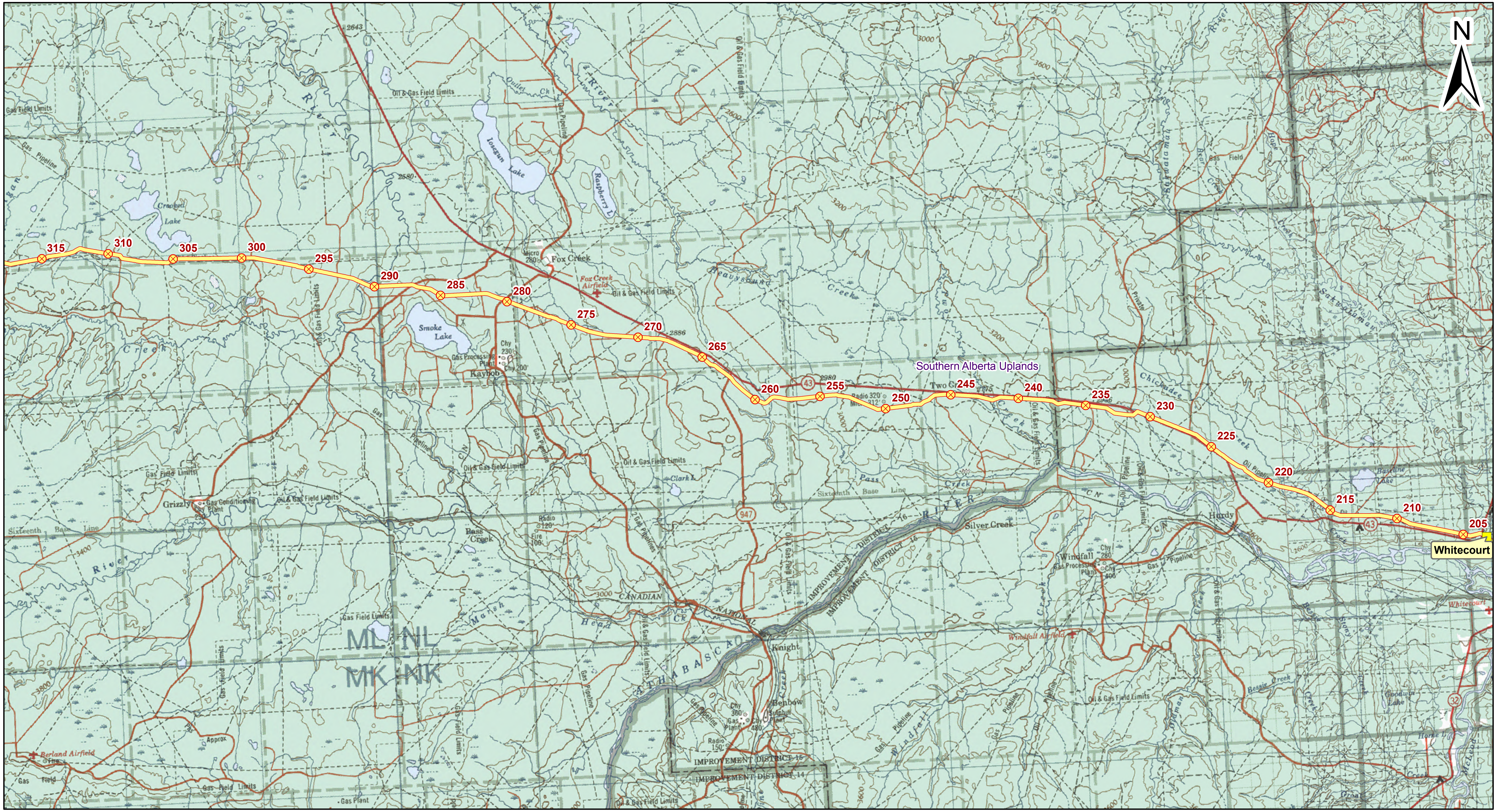

LEGEND

Kilometre Post (July 27, 2009)

Proposed Route (July 27, 2009)

Pump Station

Condensate

Condensate / Crude

Crude

Physiographic Boundary

ENBRIDGE NORTHERN GATEWAY PIPELINES

SCALE: 1:275,000

0 2 4 6

Kilometers

PROJECTION: LCC

DATUM: NAD 83

ENBRIDGE NORTHERN GATEWAY PROJECT

Route Location

KP 215 - KP 315

Physiographic Boundaries

PROJECT NUMBER: EG0926008.3001

DATE: February 5, 2010

QA/QC: DC

REFERENCE: Pipeline Route: Rev. R. July 27, 2009

CONTRACTOR: AMEC Earth & Environmental

Figure A-3

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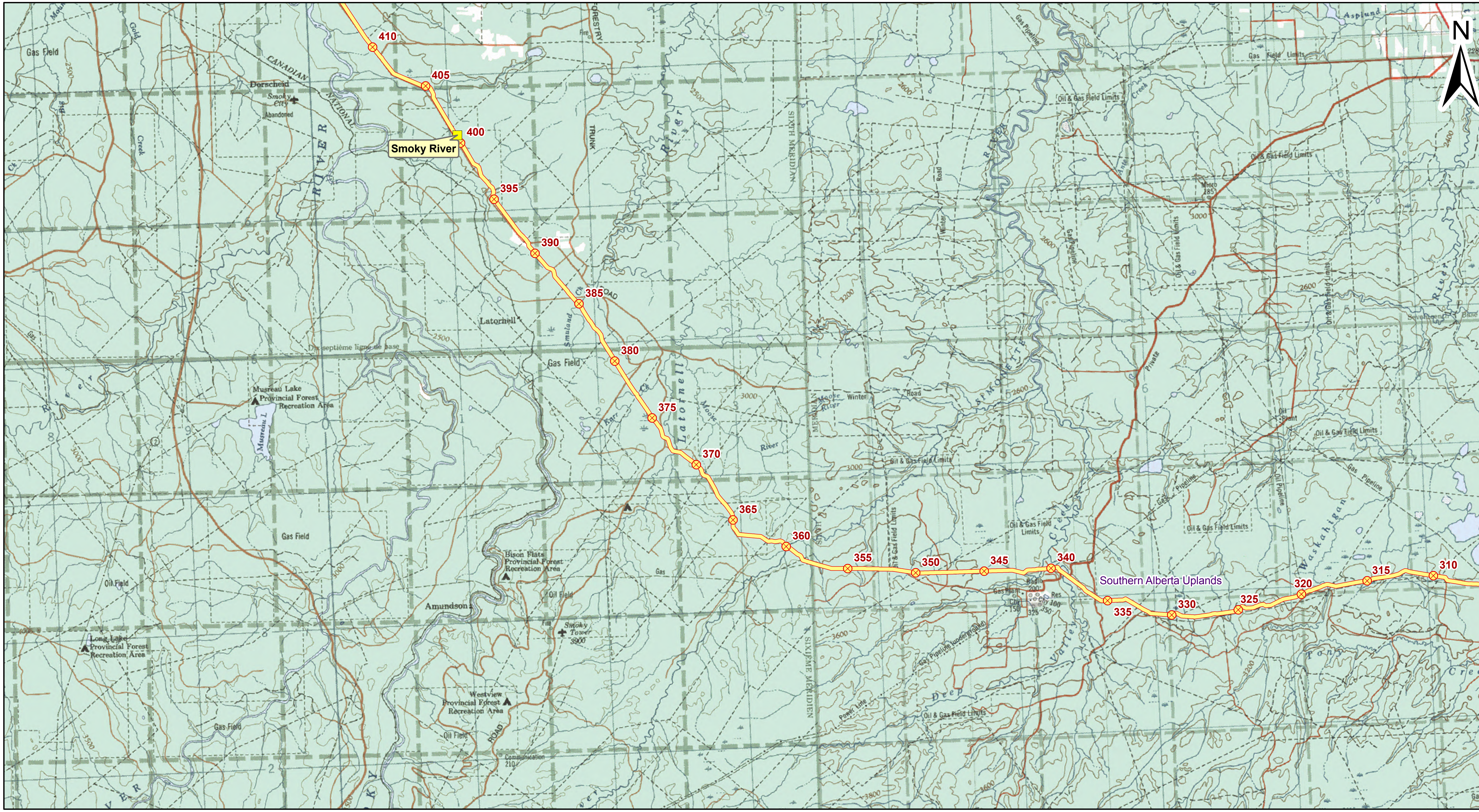

LEGEND

- Kilometre Post (July 27, 2009)
- Proposed Route (July 27, 2009)

Pump Station
- Condensate
- Condensate / Crude
- Crude
- Physiographic Boundary

ENBRIDGE NORTHERN GATEWAY PIPELINES

SCALE: 1:275,000

0 2 4 6
Kilometers

PROJECTION: LCC
DATUM: NAD 83

ENBRIDGE NORTHERN GATEWAY PROJECT

Route Location
KP 315 - KP 410
Physiographic Boundaries

PROJECT NUMBER: EG0926008.3001

DATE: February 5, 2010
QA/QC: DC

REFERENCE: Pipeline Route: Rev. R. July 27, 2009

CONTRACTOR: AMEC Earth & Environmental

Figure A-4

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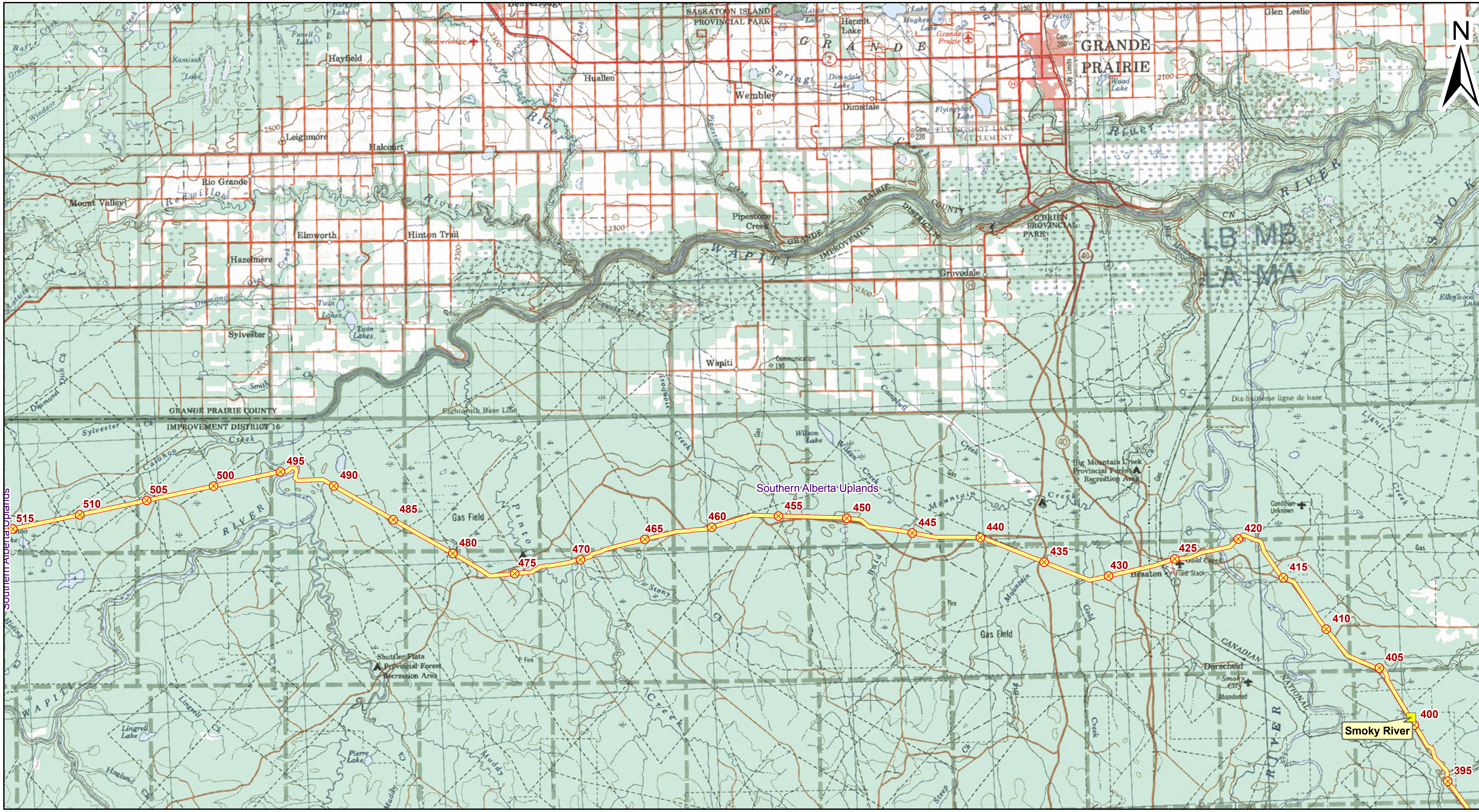

LEGEND

- Kilometre Post (July 27, 2009)
- Proposed Route (July 27, 2009)

Pump Station

- Condensate
- Condensate / Crude
- Crude
- Physiographic Boundary

SCALE: 1:275,000

0 2 4 6
Kilometers

PROJECTION: LCC

DATUM: NAD 83

ENBRIDGE NORTHERN GATEWAY PROJECT

Route Location
KP 410 - KP 515
Physiographic Boundaries

PROJECT NUMBER: EG0926008.3001

DATE: February 5, 2010

QA/QC: DC

REFERENCE: Pipeline Route: Rev. R. July 27, 2009

CONTRACTOR: AMEC Earth & Environmental

Figure A-5

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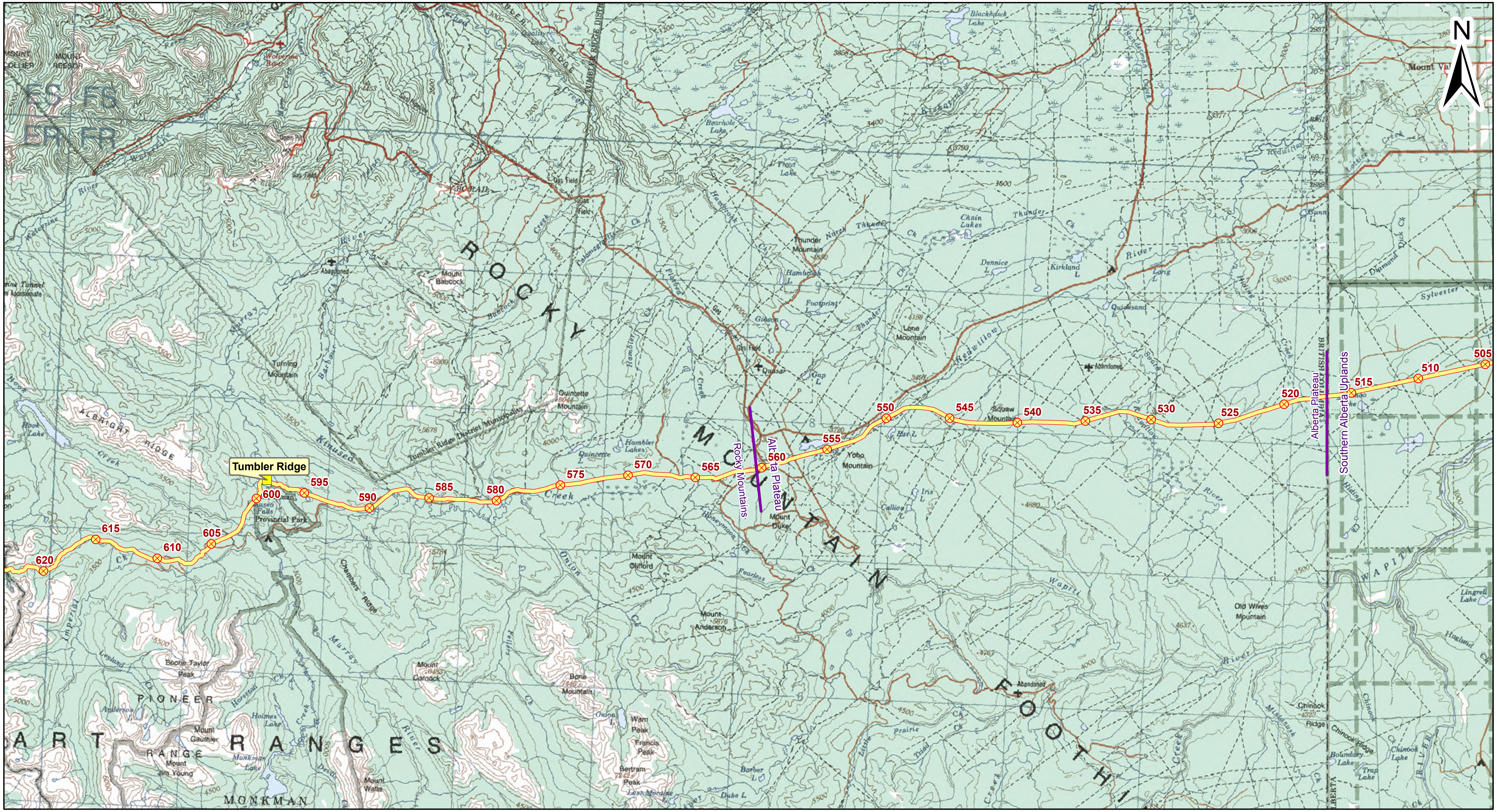


LEGEND

- Kilometre Post (July 27, 2009)
- Proposed Route (July 27, 2009)

Pump Station
- Condensate
- Condensate / Crude
- Crude
- Physiographic Boundary

SCALE: 1:275,000

0 2 4 6
Kilometers

PROJECTION: LCC
DATUM: NAD 83

ENBRIDGE NORTHERN GATEWAY PROJECT

Route Location
KP 515 - KP 620
Physiographic Boundaries

PROJECT NUMBER: EG0926008.3001

DATE: February 5, 2010
QA/QC: DC

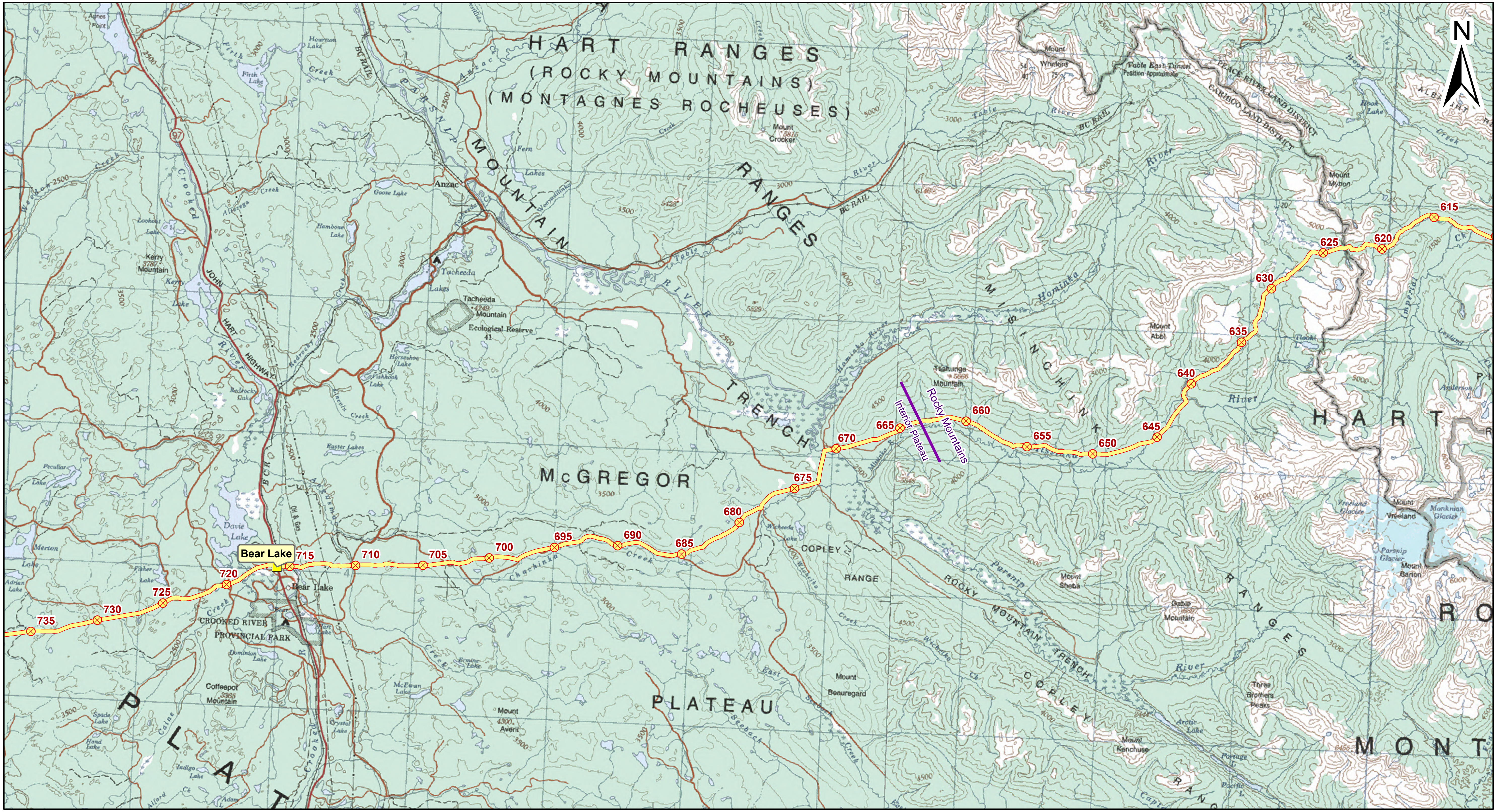
REFERENCE: Pipeline Route: Rev. R. July 27, 2009

CONTRACTOR: AMEC Earth & Environmental

Figure A-6

ENBRIDGE NORTHERN GATEWAY PIPELINES

Y:\GIS\Projects\CE\CE03210_GatewayMapping\MXD\NEB-application\NEB_route_250k_mapbook_v3.mxd



ENBRIDGE
NORTHERN
GATEWAY PIPELINES

LEGEND

- Kilometre Post (July 27, 2009)
- Proposed Route (July 27, 2009)

Pump Station
- Condensate
- Condensate / Crude
- Crude
- Physiographic Boundary

SCALE: 1:275,000

0 2 4 6
Kilometers

PROJECTION:	DATUM:
LCC	NAD 83

ENBRIDGE NORTHERN GATEWAY PROJECT

Route Location
KP 615 - KP 735
Physiographic Boundaries

PROJECT NUMBER: EG0926008.3001	
DATE: February 5, 2010	QA/QC: DC
REFERENCE: Pipeline Route: Rev. R. July 27, 2009	
CONTRACTOR: AMEC Earth & Environmental	Figure A-7

LEGEND

- Kilometre Post (July 27, 2009)
- Proposed Route (July 27, 2009)

Pump Station
- Condensate
- Condensate / Crude
- Crude
- Physiographic Boundary

ENBRIDGE NORTHERN GATEWAY PIPELINES

SCALE: 1:275,000

0 2 4 6

Kilometers

PROJECTION: LCC

DATUM: NAD 83

ENBRIDGE NORTHERN GATEWAY PROJECT

Route Location
KP 735 - KP 840
Physiographic Boundaries

PROJECT NUMBER: EG0926008.3001

DATE: February 5, 2010

QA/QC: DC

REFERENCE: Pipeline Route: Rev. R. July 27, 2009

CONTRACTOR: AMEC Earth & Environmental

Figure A-8

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LEGEND

- Kilometre Post (July 27, 2009)
- Proposed Route (July 27, 2009)

Pump Station

- Condensate
- Condensate / Crude
- Crude
- Physiographic Boundary

SCALE: 1:275,000

0 2 4 6

Kilometers

PROJECTION: LCC

DATUM: NAD 83

ENBRIDGE NORTHERN GATEWAY PROJECT

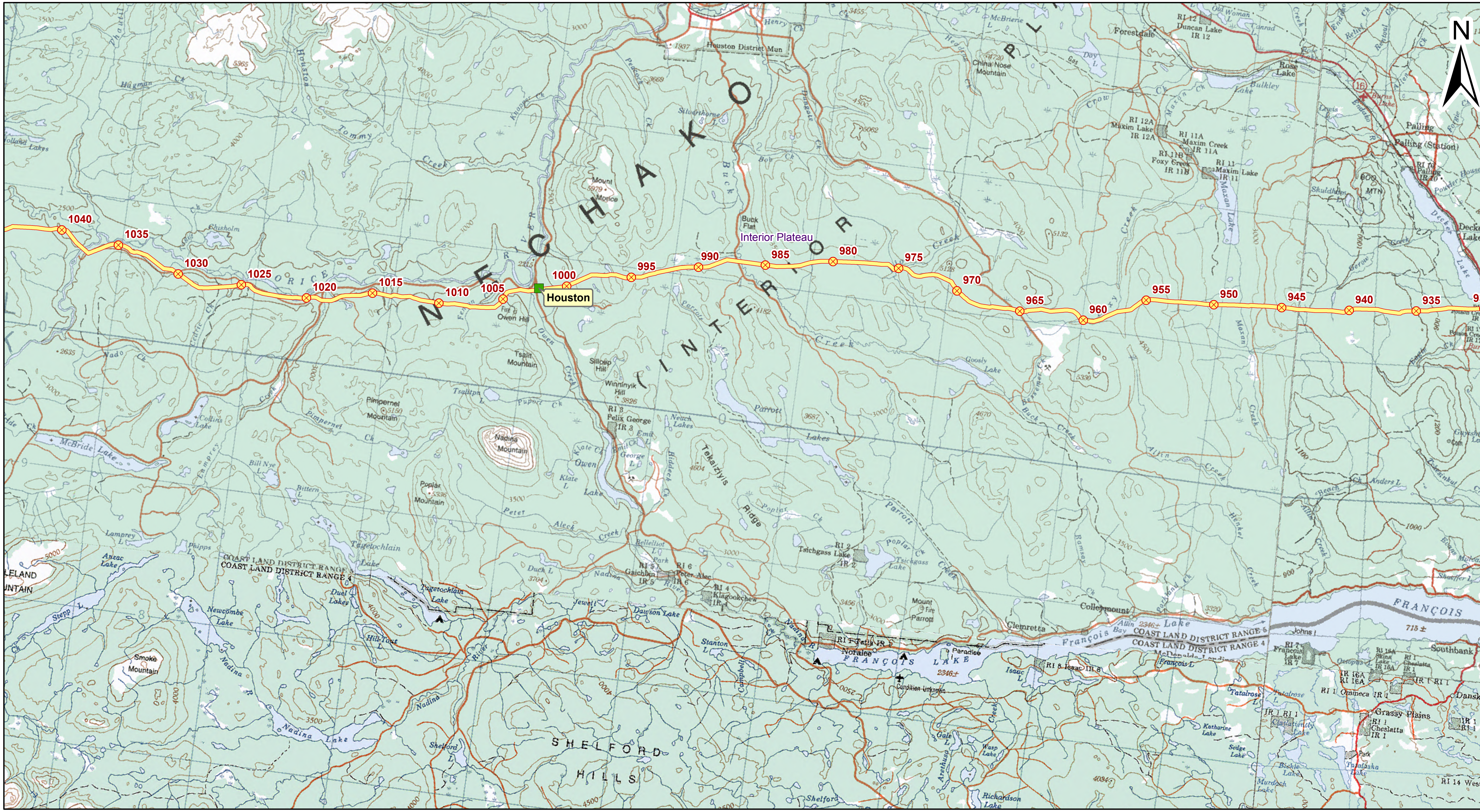
Route Location

KP 840 - KP 940

Physiographic Boundaries

PROJECT NUMBER:	EG0926008.3001
DATE: February 5, 2010	QA/QC: DC
REFERENCE:	Pipeline Route: Rev. R. July 27, 2009
CONTRACTOR: AMEC Earth & Environmental	Figure A-9

Y:\GIS\Projects\CE\CE03210_GatewayMapping\MXD\NEB-application\NEB_route_250k_mapbook_v3.mxd



ENBRIDGE NORTHERN GATEWAY PIPELINES

LEGEND

- Kilometre Post (July 27, 2009)
- Proposed Route (July 27, 2009)

Pump Station

- Condensate
- Condensate / Crude
- Crude
- Physiographic Boundary

SCALE: 1:275,000

0 2 4 6

Kilometers

PROJECTION: LCC

DATUM: NAD 83

ENBRIDGE NORTHERN GATEWAY PROJECT

Route Location

KP 940 - KP 1040

Physiographic Boundaries

PROJECT NUMBER: EG0926008.3001

DATE: February 5, 2010

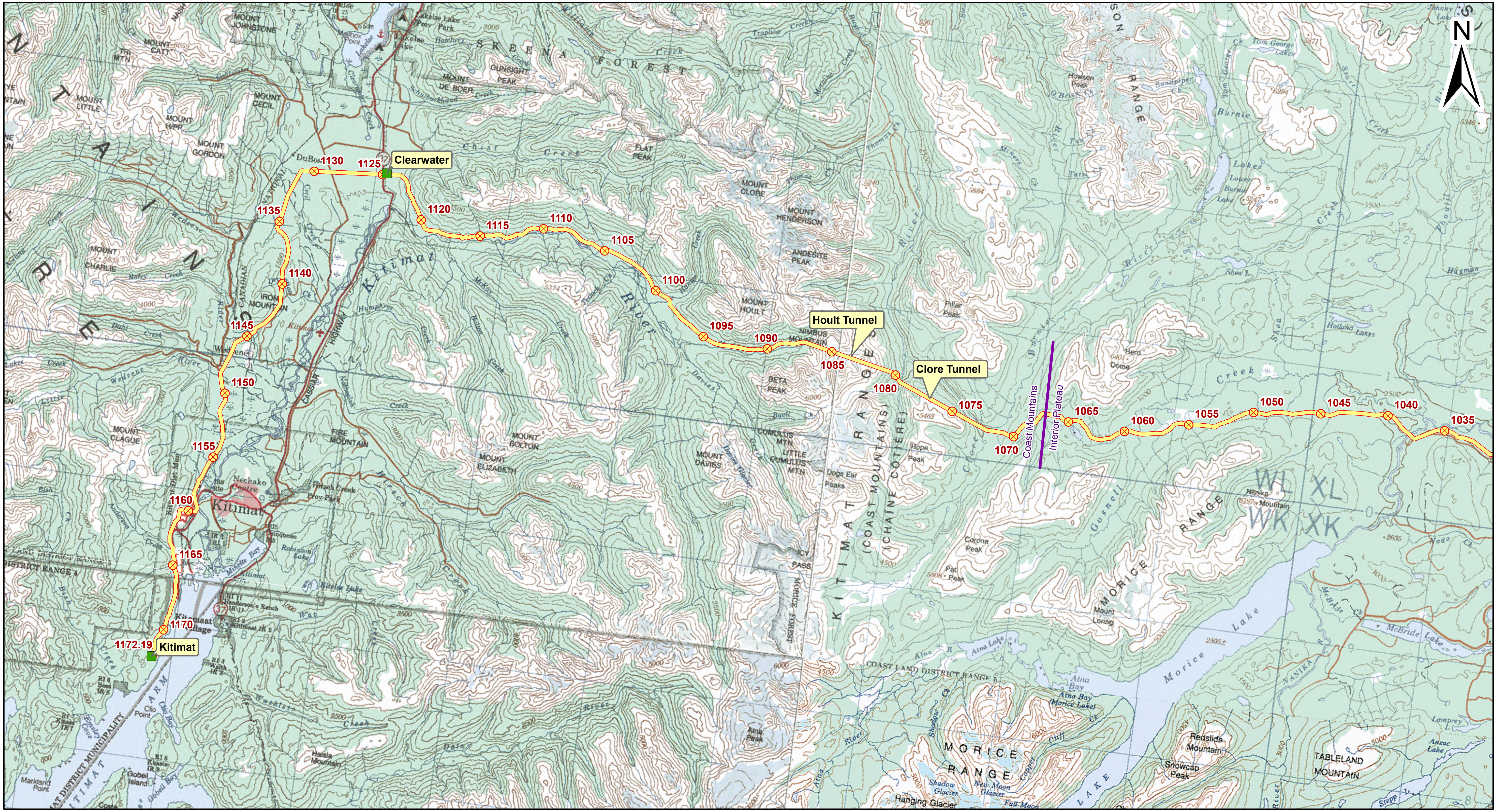
QA/QC: DC

REFERENCE: Pipeline Route: Rev. R. July 27, 2009

CONTRACTOR: AMEC Earth & Environmental

Figure A-10

Y:\GIS\Projects\CE\CE03210_GatewayMapping\MXD\NEB-application\NEB_route_250k_mapbook_v3.mxd



LEGEND

- Kilometre Post (July 27, 2009)
- Proposed Route (July 27, 2009)

Pump Station

- Condensate
- Condensate / Crude
- Crude
- Physiographic Boundary

ENBRIDGE NORTHERN GATEWAY PIPELINES

SCALE: 1:275,000

0 2 4 6
Kilometers

PROJECTION: LCC

DATUM: NAD 83

ENBRIDGE NORTHERN GATEWAY PROJECT

Route Location
KP 1040 - KP 1172.19
Physiographic Boundaries

PROJECT NUMBER: EG0926008.3001

DATE: February 5, 2010

QA/QC: DC

REFERENCE: Pipeline Route: Rev. R. July 27, 2009

CONTRACTOR: AMEC Earth & Environmental

Figure A-11

Y:\GIS\Projects\CE\CE03210_GatewayMapping\MXD\NEB-application\NEB_route_250k_mapbook_v3.mxd

APPENDIX B

Summary Table B-1

Table B-1 Preliminary Summary of Geotechnical Conditions-Rev R

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
This table summarizes the preliminary geotechnical aspects of the pipeline route for the Enbridge Northern Gateway Project. This table is subject to revision as further geotechnical investigations occur and additional information is obtained.			
0.0	2.9	Flat to undulating terrain at and near proposed Bruderheim Station at east end of route. Congested area with limitations on routing due to land ownership considerations and other pipelines. Surficial Geology (Bayrock, 1972): Sand dunes and sheet sand, dunes 3 to 15 m thick, sheet sand is typically thin likely overlying till at depth. Toward the east, thinner aeolian sand may overlie glacial till. Local areas of muskeg in closed depressions. Bedrock Geology (Hamilton et al, 1999): Belly Valley Group (thick bedded grey to greenish grey feldspathic sandstone, grey clayey siltstone, grey and green mudstone, concretionary ironstone. Non-marine.) Andriashek (1987a and 1987b) indicates that there is a major buried valley (Beverly Valley) that trends parallel to the modern North Saskatchewan valley. At the study area, the valley is centered slightly east of the modern valley with drift thicknesses in excess of 40 m at the center of the valley. In the segment under discussion, depths to bedrock of 30 to 40 m are typical. The valley is likely infilled with clay, sand and till with layers of cobbles or boulders.	Some dunes and sand deposits may be erodible. Mulching may be required together with revegetation of disturbed areas.
2.9	5.3	**North Saskatchewan River – KP 4.1**: Moderately steep to steep approach slope into the valley on the east side is an estimated 25 m high. There is a terrace approximately 400 m wide on the east side of the river. Banks into the river is are approximately 8 m high and also steep. On the west side of the river there is a terrace approximately 200 m wide. The route deviates to the south to run up the west approach slope of the river valley south of a tributary stream gully. Shallow sliding in gully was avoided by routing. The routing in this area was dictated by the presence of other pipelines and existing land ownership and use. Preliminary geotechnical ground examinations indicated no major stability concerns for areas outside of tributary valley slopes. Shallow rock on reported west side, excavated using ripping. Surficial Geology (Bayrock, 1972): Outwash sand to thicknesses of 1 to	**Tight area** due to presence of other pipelines and terrain features. Detailed and comprehensive ground and surface water control measures will be required. These measures should be coordinated with existing and planned measures for other pipelines in the area. **Open Cut Crossiing**: A conventional trenched crossing appears to be geotechnically and hydrotechnically feasible based on work to date and on the method used by other adjacent pipelines. Other recent pipelines crossings are understood to have been trenched. An isolated crossing is not feasible due to flows being too high.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		6 m overlying till(?) and Beverly Valley infill deposits. Alluvial sand to silt on terraces near river. Bedrock Geology (Hamilton et al, 1999): Belly Valley Group, as above.	
5.3	21.0	Undulating upland topography. Surficial Geology (Bayrock, 1972): Sand dunes and sheet sand, dunes 3 to 15 m thick, sheet sand is typically thin, overlying till. Some areas of exposed till. GEM terrain mapping suggested glaciofluvial and shallow glaciolacustrine deposits may also be present. Bedrock Geology (Hamilton et al, 1999): Belly Valley Group (thick bedded grey to greenish grey feldspathic sandstone, grey clayey siltstone, grey and green mudstone, concretionary ironstone. Non-marine). Andriashek (1987a and 1987b) indicates drift thicknesses of 10 to 20 m so bedrock is not expected to be exposed.	No significant geotechnical issues identified.
21.0	23.4	**Tributary Creek to Sturgeon River**: Sturgeon River is to the south. Moderate slopes to 25 m high into and out of wide valley (former glaciofluvial meltwater valley). Railway crossing near crest of east approach slope. Surficial Geology (Bayrock, 1972): Outwash sand and gravel to thicknesses of 6 m overlying bedrock. Bedrock is exposed to the south in the Sturgeon River valley. GEM terrain mapping suggested glaciofluvial and shallow aeolian and glaciolacustrine deposits may also be present. Bedrock Geology (Hamilton et al, 1999): Belly Valley Group, as above.	Ground and surface water control required on slopes.
23.4	33.1	Flat to gently sloping terrain Surficial Geology (Bayrock, 1972): Glacial till with pitted deltas (sand with lesser amounts of silt and clay) to west. GEM terrain mapping suggested glaciolacustrine deposits may also be present. Bedrock Geology (Hamilton et al, 1999): Belly Valley Group, as above.	No significant geotechnical concerns identified.
33.1	40.7	Gently sloping terrain. Surficial Geology (Bayrock, 1972): Glaciolacustrine high plastic clays with silt, may be varved. Lesser amounts of till and mixed deposits. Bedrock Geology (Hamilton et al, 1999): Horseshoe Canyon Formation (sandstone, mudstone and shale, scattered coal and bentonite beds, minor limestone, non-marine). Bedrock probably not exposed based on drift thicknesses varying from 10 to 40 m (Andriashek, 1987a and 1987b)	No significant geotechnical concerns identified.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
40.7	63.8	Flat to undulating terrain. Occasional canals or canalized streams. A few other small stream crossings. Surficial Geology (Bayrock, 1972): Mainly glacial till. GEM terrain mapping suggested glaciolacustrine veneers and blankets may be present. Bedrock Geology (Hamilton et al, 1999): Horseshoe Canyon Formation (sandstone, mudstone and shale, scattered coal and bentonite beds, minor limestone, non-marine). Bedrock probably not exposed based on drift thicknesses varying from 10 to 40 m (Andriashek, 1987a and 1987b)	No significant geotechnical concerns identified. KP 41.6: Little Egg Creek. Narrow irrigation canal or canalized stream acting as a drainage ditch. Covered with weeds, bottom not visible from air. Other apparently similar canalized streams/drainage ditches exist in the area.
63.8	64.1	**Riviere Qui Barre – KP 63.9** Meandering stream with several cut-off and oxbow channels. Surficial Geology (Shetsen 1990): Local peat deposits over moraine, minor amounts of water sorted material and bedrock exposures. Typical thicknesses of 10 m, but may vary significantly. Pawlowicz and Fenton (1995b) indicate thicknesses up to 15 m with bedrock exposures to the west and south. Local peat deposits overlying till as above. GEM terrain mapping indicates scattered glaciolacustrine veneers. Bedrock Geology as above.	Sagbend locations will need to consider meandering channel, oxbows and the potential for future lateral erosion.
64.1	80.2	South of Deadman and Kakina Lakes. Level to slightly undulating terrain. Surficial Geology (Lehner, 1979): Shallow till overlying bedrock. Possible exposures, but bedrock is weak and will tend to weather recessively. Bedrock may be encountered during trenching, but most will likely be rippable. GEM terrain mapping indicates scattered glaciolacustrine veneers, particularly near east end of segment. Bedrock Geology (Hamilton et al, 1999): Horseshoe Canyon Formation as above.	No geotechnical concerns identified. Possible local shallow weak rock but most will be rippable.
80.2	108.7	South of Oldman Lake. Crossings of tributary streams, some with shallow small lakes or ponds. Parallel to existing pipelines RoW. Surficial Geology (Lehner, 1979): Rolling to undulating till. KP 89.3 to 92.4 (approx.): glaciolacustrine clay. GEM terrain mapping indicates scattered glaciolacustrine and organic veneers. Bedrock Geology: (Hamilton et al, 1999). Horseshoe Canyon Formation as above. Bedrock probably not exposed.	No significant geotechnical concerns identified.
108.7	130.6	Parallel to existing pipeline RoW.	No geotechnical concerns identified. Possible local

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Surficial Geology (Lehner, 1979): Rolling to undulating glacial till overlain by veneer to blanket of glaciolacustrine clay. Areas of thin till or possible bedrock exposures toward end of segment. Bedrock Geology (Hamilton et al, 1999): Horseshoe Canyon Formation (sandstone, mudstone and shale, scattered coal and bentonite beds, minor limestone, non-marine). Possible exposures toward end of segment, but bedrock is weak and will tend to weather recessively. Bedrock may be encountered during trenching, but most will likely be rippable.	shallow weak rock toward end of segment. Most bedrock is expected to be rippable KP 126.7: Small meandering creek with no water in channel at the time of the reconnaissance (September 2006) about 100 m upstream of the crossing. Meandering, low gradient, with weeds and/or algae. .
130.6	132.2	**Pembina River – KP 131.6** Crossing is southwest of Sangudo. Parallel to Alliance Pipeline which is located to the south. Meandering channel incised up to 30 m deep relative to surrounding glaciolacustrine plain. Several levels of terraces formed during river downcutting into valley fill. West approach slope is higher and steeper than east approach slope. Surficial Geology (Lehner, 1979) Major regional deposit is glaciolacustrine clay plain, into which the slightly incised (up to 30 m or so) valley and terraces have been eroded/deposited. Carlson (1970) indicates bedrock elevations close to the bottom of the river valley. Pawlowicz and Fenton (1995a) indicate that the area is at the headwaters of the Dapp preglacial valley complex. There were flaggy bedrock pieces in channel which may indicate that the channel is close to bedrock. Bedrock Geology: (Hamilton et al, 1999): Horseshoe Canyon Formation as above.	River is tending to migrate to northwest. Potential for cutoffs upstream and downstream which could affect scour or lead to local degradation. Meander bend southeast of crossing could approach crossing and needs to be included in design. Location relative to Alliance should be checked. Route on west approach slope may be on sidehill above an old oxbow. **Directionally Drilled Crossing**: Appears to be feasible on a preliminary basis subject to the extent and depth of deposits in the preglacial valley (if present). Further investigators would be required to determine feasibility. **Open Cut Crossing**: Feasible. Isolation appears to be feasible using dam and pump (low flows) or fluming except during peak runoff. River is tending to migrate to northwest. Potential for cut-offs upstream and downstream which could affect scour or lead to local degradation. Meander bend southeast of crossing could approach crossing and needs to be included in design.
132.2	138.1	In this segment and to the west: Parallel to existing Alliance Pipeline RoW. Surficial Geology (Lehner, 1979): Major regional glaciolacustrine clay	No significant geotechnical concerns identified.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		plain continues. Pawlowicz and Fenton (1995b) indicate regional depths to bedrock of up to 15 m. There may be shallow bedrock toward end of segment. GEM terrain mapping also indicates scattered organic veneers. Bedrock Geology: (Hamilton et al, 1999): Scollard Formation (grey feldspathic sandstone, dark grey bentonitic mudstone, thick coal beds, non-marine).	
138.1	138.9	**Paddle River – KP 138.2** Proposed crossing is southwest of the Highway 43 crossing and 2.5 km northeast of Paddle River Dam; north of existing Alliance crossing. River valley is incised 30 to 50 m relative to surrounding flat to gently rolling terrain. The river meanders on a flat valley floor in the wide valley with gently to moderately sloping approach slopes. Bedrock may be close to exposure on the east valley slope (based on work 1 to 2 km away). There was a beaver pond in the river upstream of the existing crossing. Very low approach slope on east. West slope is approx. 20 m high and steep. No problems with stability identified from air; however, extremely high plastic clays occur in the valley which may be prone to slides. Surficial Geology (Lehner, 1979) Major regional deposit is glaciolacustrine clay plain, into which the valley has been eroded 30 to 50 m. Alluvium along channel. AMEC experience in the general area 1 to 2 km away indicates approximately 1.5 m of alluvium underlain by about 9 m of glaciolacustrine clay, underlain by about 9 m of preglacial sands, underlain by bedrock. Bedrock (Hamilton et al, 1999): Scollard Formation (grey feldspathic sandstone, dark grey bentonitic mudstone, thick coal beds, non-marine). Bedrock may be close to exposure along the east valley slope.	Extensive high plastic glaciolacustrine clay deposits underlying approach slopes. Some of these deposits are jointed and slickensided, perhaps as a result of melting of ice blocks soon after deposition. Geotechnical field review of stability of approach slopes recommended. Lateral erosion considerations with respect to approach slope stability and sagbend locations should also be considered. Ground and surface water control will be required. Potential for long term meander cut-offs upstream and downstream. Lateral erosion needs to be considered. Bank may be locally armoured at Alliance. **Open Cut Crossing**: Feasible. An isolated crossing appears feasible using dam and pump (low flows) or fluming at most times of year. There is riprap on the northwest side of the river at the existing pipeline crossing adjacent to the route which would likely need to be extended. West slope would have to be graded out.
138.9	160.3	Continuing parallel to Alliance Pipeline RoW and other pipeline RoWs. Flat terrain with a few areas of muskeg. Surficial Geology (Alberta Research Council, 1979): Glaciolacustrine clay plain, minor shallow muskegs. Bedrock Geology: (Hamilton et al, 1999): Scollard Formation as above.	No geotechnical concerns identified.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
160.3	163.3	Alliance Pipeline deviates to north around areas of muskeg, proposed route follows Alliance. Surficial Geology (Shetsen, 1990): Glaciolacustrine clay. Alberta Research Council (1976a) suggests that bedrock may be relatively shallow (0 to 15 m). Bedrock Geology: (Hamilton et al, 1999): Scollard Formation as above.	No geotechnical concerns identified.
163.3	164.2	**Little Paddle River – KP 164.0** Meandering stream, low approach slopes. Surficial Geology (Shetsen, 1990): Glaciolacustrine clay. Alberta Research Council (1976a) suggests that bedrock may be relatively shallow (0 to 15 m). Bedrock Geology: (Hamilton et al, 1999): Scollard Formation as above.	**Open Cut Crossing**: Isolation appears to be feasible. An open cut crossing appears possible from geotechnical and hydrotechnical points-of-view.
164.2	178.5	Parallel to existing pipeline RoWs. Gently to locally moderately sloping terrain to the east with several small stream channels and areas of erosion. Surficial geology: Shetsen (1990) suggests that bedrock may be relatively shallow (0 to 15 m). GEM terrain mapping suggests mostly glaciolacustrine sediments with small areas of organic veneers east of KP 168.6 with more moraine and glaciofluvial sediments to west. Bedrock geology (Hamilton et al, 1999): Underlain by Upper Paskapoo Formation (green to greenish grey thick bedded calcareous cherty sandstone, grey and green siltstone and mudstone, thin limestone, coal and tuff beds. Non-marine.)	Thick sandstone beds and lenses in the Paskapoo Formation may require blasting. Note the presence of chert in the formation which will increase drill bit wear. Ground and surface water control on sloping terrain.
178.5	185.2	South approach slope to Athabasca River valley. Parallel to north side existing pipeline RoWs. Possible ancient deep-seated slides, which may be partially buried in more recent alluvium along toe. Surficial geology: Shetsen (1990) Ice contact glaciolacustrine and fluvial deposits. Bedrock geology (Hamilton et al, 1999): Scollard Formation (grey feldspathic sandstone, dark grey bentonitic mudstone, thick coal beds, non-marine).	A route on the south side of existing RoW is not recommended geotechnically due to the locations of various existing infrastructure and terrain considerations including. **Stability**: Possible eroded old deep-seated slide blocks east of KP 183.6 (approx.) suggest that deep-seated slide movements on underlying weak clay layers might have occurred in parts of area. Helicopter reconnaissance did not indicate any evidence of recent movement. Ground and surface water control on sloping terrain.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
185.2	186.1	Flat terrain south of Athabasca River. Surficial geology: Shetsen (1990) Ice contact glaciolacustrine and fluvial deposits. GEM terrain mapping and local observations indicate terrain modified by erosion and deposition of Athabasca River. Bedrock geology (Hamilton et al, 1999): Scollard Formation (grey feldspathic sandstone, dark grey bentonitic mudstone, thick coal beds, non-marine).	Bored crossing of CNR near start of segment could be on transition zone between shallow till above and deeper ice contact deposits in this segment. The detailed geological conditions should be checked.
186.1	187.9	**Athabasca River – KP 187.3** The valley has a broad terrace and floodplain south of the river with several channels parallel to the river up to 775 m south of the main channel. The valley is shallow on the south side and approximately 75 m deep on the north side. The route parallels an existing powerline RoW 300 m to the west. There is a deep seated slide west of the powerlines and another slide block below the powerlines. There is a sagpond on the lower terrace directly east of the powerlines. To the east, the slides along the steep slopes above the river are smaller and typically shallow. Surficial geology: Alberta Research Council (1976a) suggests that the center of the buried bedrock channel is south of the river at elevations of 670 m (2200 ft) or deeper compared to surface elevations of 685 m (2250 ft). That is, the channel bottom may be within 15 to possibly 30 m below surface south of the river. This is consistent with the results of the investigation drilling at Option A. Bedrock geology: Bedrock is close to exposure along portions of the north valley slope. Dawson, et al., (1998) at the initial crossing location 3 km west of the Rev R alignment indicates consists Lower Scollard Formation (grey feldspathic sandstone, dark grey bentonitic mudstone, thick coal beds, non-marine), which is the likely reason for the deep-seated slides in this area. This rock appears to continue to the powerlines west of Rev R where there is a deep-seated slide block at the toe of the slope. The bedrock at the preferred alignment approximately 300 m east of the powerlines apparently consists of the Upper Horseshoe Canyon Formation (sandstone, siltstone and coal	Due to stability conditions and a sagpond directly east of the powerlines, the geotechnically recommended alignment is approximately 300 m east of the powerlines. On the north approach slope, the route is on a ridge with local groundwater piping, groundwater blow-off failures (small) and erosion on north approach slope. The ridge would need to be graded for a pipeline route, if required. Comprehensive planning for grading and for ground and surface water drainage and control would be recommended. Drilling investigations north of the river encountered ice rafted (or thrust) bedrock overlying a thin cobble layer of variable thickness overlying sandstone, siltstone and mudstone with a few extensively fractured zones. Hydrotechnical review indicates that lateral erosion and re-occupation of existing channels south of the present main channel are important considerations. The crossing will need to be below lateral erosion and scour depths (deep cover) from south of the road south of the crossing to the toe of the north approach slope. **Directionally Drilled Crossing**: On a preliminary basis, directional drilling is assessed as feasible but may be difficult due to extensive circulation losses during

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		seams with less bentonitic or high plastic clay or mudstone).	investigative drilling and the presence of an ice-thrust rock layer with underlying gravel. Special methods might be required to deal with these issues. Further investigations and review are anticipated during detailed design. **Open Cut Crossing**: Based on slope stability and overall channel morphology, appears feasible. Crossing would be relatively long and would require deep excavation. Isolation is not feasible due to flow conditions. Diversion methods are not recommended due to configuration of subchannels (would require significant excavation and widening).
187.9	199.3	Route runs north, turns to west and parallels existing pipelines including Alliance pipeline near west end of segment. Level to gently sloping topography north of Athabasca River. <u>Surficial geology</u>: Shetsen (1990). Aeolian deposits (sand dunes) up to 7 m thick overlying glacial till and possible glaciolacustrine and preglacial deposits. Glacial till directly to the north. GEM terrain mapping suggests till and glaciolacustrine deposits with organic veneers. <u>Bedrock</u> (Hamilton et al, 1999): Scollard Formation (grey feldspathic sandstone, dark grey bentonitic mudstone, thick coal beds, non-marine.	No significant geotechnical issues identified.
199.3	201.1	<u>**Sakwatamau River – KP 200.4**</u> The east approach slope is higher than 45 m with moderately steep slopes steepening to steep slopes near the bottom of the valley. The west approach slope is low and gently sloped. The valley is an old meltwater channel with a bottom width of almost 1 km. The stream is meandering with several old cut off channels. Some of the old channels were eroding and may carry significant flows in the future. Due to congestion of existing pipelines (apparently Alliance and Peace), future conventional crossings will be significantly longer than existing crossings due to the configuration of the back channels, particularly on the west side of the valley. <u>Surficial geology</u> (Shetsen 1990): Minor aeolian deposits and draped glacial till on upland areas. Alluvial sediments along valley. Alberta Research Council (1976a) suggests that bedrock may be close to exposure along the bottom of the valley. GEM terrain mapping also indicated glaciofluvial sediments.	**Stability**: Area not yet reviewed on LiDAR or on ground. Further geotechnical review of stability of approach slopes is recommended. No indication of stability issues based on aerial reconnaissance. A cut off meander may form in the future upstream (north) of the proposed crossing which could affect future lateral erosion conditions. There are also subchannels on both the east and west sides. The tendency of the stream channel to migrate laterally or reoccupy the subchannels will need to be considered during the design of the crossing and the locations of the sagbends. Crossing will likely be relatively long. **Open Cut Crossing**: Appears feasible based on geotechnical and channel morphology. Crossing will be

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Bedrock (Hamilton et al, 1999): Scollard Formation (grey feldspathic sandstone, dark grey bentonitic mudstone, thick coal beds, non-marine.	relatively long since the sagbends will probably have to be east and west of backchannels that are eroding. Isolation using dam and pump methods would be feasible over the winter period. Flume or superflume isolation methods would be feasible in the fall.
201.1	203.1	Parallel to existing pipelines and powerline RoWs. Directly west of Sakwatamau River and south tributary to Sakwatamau River (approximately KP 202.0 west to KP 203.6), Existing Alliance pipeline RoW is approximately 15 to 20 m south of the edge of a moderately steep slope with shallow to moderately deep slides. Outside meander bends of old channels of the river and tributary are at the toe of the slope at intervals over approximately 1 km. Surficial geology (Shetsen 1990): Aeolian deposits (sand dunes) up to 7 m thick. GEM terrain mapping suggests mixture of moraine, organics and some areas of glaciofluvial and glaciolacustrine sediments. Bedrock geology (Hamilton et al, 1999): Upper Paskapoo Formation (green to greenish grey thick bedded calcareous cherty sandstone, grey and green siltstone and mudstone, thin limestone, coal and tuff beds; non-marine.)	**Tight area**: Potentially tight area, depending on location of Alliance Pipeline on their RoW. Providing the pipelines are located toward the south, there appeared to be sufficient room to use the north part of the Alliance RoW for workspace and to install the Gateway pipelines between the edge of the Alliance RoW and the crest of the slope. Further checks and survey in this area are recommended. **Stability**: There are a series of moderately deep slides along the Sakwatamau valley slopes immediately to the northeast of the route. Erosion, sedimentation and surface/ground water control will be required.
203.1	215.9	At start of segment, route parallels local roads north of an area of recent and planned development. To west, route follows an existing RoW (apparently Peace pipeline) north of Highway 43. Surficial geology (Shetsen 1990): Aeolian deposits (sand dunes) up to 7 m thick at east end of segment. Most of segment is underlain by draped glacial till of varying thicknesses. GEM terrain mapping indicates undulating till with some areas of organics and increasing areas of glaciolacustrine sediments to the west. Bedrock geology (Hamilton et al, 1999): Upper Paskapoo Formation (green to greenish grey thick bedded calcareous cherty sandstone, grey and green siltstone and mudstone, thin limestone, coal and tuff beds; non-marine.)	No significant geotechnical issues identified.
215.9	216.1	Crossing of small creek. East approach slope is about 50 m high, gentle slopes steepening at toe. West approach slope is much lower, and steep.	Grading back of steep slopes segments and moving graded material to behind crest of slope may be required. Trench blocks (possibly with drains) and cross berms will be required.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
216.1	218.6	Flat to gently rolling upland terrain northeast of Chickadee Creek. Local areas of muskeg and wet ground. Surficial geology Shetsen (1990): Aeolian deposits (sand dunes) up to 7 m thick at east end of segment. Most of segment is underlain by draped glacial till of varying thicknesses. GEM terrain mapping indicate mostly undulating till with minor areas of glaciolacustrine sediments and several areas of organics. Bedrock geology (Hamilton et al, 1999): Upper Paskapoo Formation (green to greenish grey thick bedded calcareous cherty sandstone, grey and green siltstone and mudstone, thin limestone, coal and tuff beds; non-marine.)	Install trench blocks as required near edges of wet areas to prevent drainage into nearby creek channels beyond ends of segment.
218.6	219.4	**Chickadee Creek – KP 219.0** Low approach slopes that appeared to be stable from air. Flat valley bottom with meandering creek. Surficial geology Shetsen (1990): Minor aeolian deposits and draped glacial till on upland areas. Alluvial sediments along valley. Alberta Research Council (1976b) suggests that bedrock may be close to exposure along the bottom of the valley. Bedrock geology (Hamilton et al, 1999): Upper Paskapoo Formation (green to greenish grey thick bedded calcareous cherty sandstone, grey and green siltstone and mudstone, thin limestone, coal and tuff beds; non-marine). Scollard Formation as discussed above could occur in bottom of valley.	Creek is meandering across the flat valley bottom between the toes of the valley slopes. Locations of sagbends will need to consider lateral erosion along meandering creek. Likely a relatively long crossing will be required to put the pipelines below scour depth across the creek. **Open Cut Crossing**: Feasible. Isolation appears feasible. Trench blocks (possibly with drains) and cross berms on approach slopes to control ground and surface water.
219.4	241.2	At start of segment, route transitions from Chickadee Creek crossing to parallel to Alliance Pipeline. Parallel to the north side of existing pipeline RoW, crosses existing pipeline and Highway 47 (KP 231.2) to south side of existing pipeline RoW and continues to west. Surficial geology (St. Onge, 1966). East end of segment up to approximately highway crossing: Glaciofluvial silty sand and sand with minor gravel. The deposits extend to the northwest along the Chickadee Creek valley (ancestral meltwater channel). To the east and west, mainly till and hummocky till deposits. Pawlowicz and Fenton (1995b) suggest that bedrock may be shallow in parts of the segment, although no areas of bedrock outcrop are shown on St. Onge (1966).	No geotechnical concerns identified.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Local small shallow muskeg areas in occasional closed depressions and along small streams. GEM terrain mapping indicates mostly till with some areas of glaciolacustrine sediments and scattered areas of organics. Bedrock geology (Hamilton et al, 1999): Underlain by Upper Paskapoo Formation as above.	
241.2	242.8	**Two Creek – KP 242.0** Meandering creek in old glaciofluvial meltwater channel up to 60 m deep (east side). West approach slope is much lower. Route may be on sideslope on the west approach slope. Surficial geology (St. Onge, 1966). Mainly till and hummocky till deposits. Pawlowicz and Fenton (1995b) suggest that bedrock may be shallow in parts of the segment, although no areas of bedrock outcrop are shown on St. Onge (1966). Local small shallow muskeg areas in occasional closed depressions and along small streams. GEM terrain mapping indicates mostly till on the east side, fluvial sediments along the valley bottom and areas of glaciolacustrine sediments on the west approach slope and crest area. Scattered areas of organics. Bedrock geology (Hamilton et al, 1999): Underlain by Upper Paskapoo Formation as above.	Meandering stream with numerous cutoffs. Crossing may have to be below scour depth across valley bottom. LiDAR not available. Area has not been checked geotechnically ton ground. Stability of slopes should be checked geotechnically in field. No evidence of sliding identified from helicopter reconnaissance. Surface and ground water control required on approach slopes. **Open Cut Crossing**: Appears feasible based on geotechnical and channel morphology. Crossings will likely be relatively long since they sagbends will probably have to be east and west of backchannels that are eroding laterally. Isolation using dam and pump would be feasible at most times of the year.
242.8	258.4	Upland terrain. Proposed route deviates to the south, leaving the existing Alliance RoW and highway at approximately KP 245.4. Surficial geology (St. Onge, 1966): Mainly till and hummocky till deposits. Local small shallow muskeg areas in occasional closed depressions and along small streams. Pawlowicz and Fenton (1995b) suggest that bedrock may be shallow in parts of the segment, although no areas of bedrock outcrop are shown on St. Onge (1966). GEM terrain mapping suggests mostly moraine with areas of glaciolacustrine sediments near east end of segment. Several areas of shallow organics. Bedrock geology (Hamilton et al, 1999): Upper Paskapoo Formation as above. Alberta Research Council (1976b) suggests that bedrock may be shallow across much of area.	No geotechnical concerns identified.
258.4	259.3	**Iosegun River – KP 259.1** Meandering river in old glaciofluvial meltwater channel. Bottom of channel is approximately 400 m wide. There is an overflow channel along the toe of the east slope and the bottom of the valley is covered	**Open Cut Crossing**: Feasible geotechnically on a preliminary basis, but some areas of extensive grading through steep bedrock segments on east slope. A sawdust deposit from an old sawmill would also probably have to be

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		with muskeg. East approach slope is at least 75 m high with steep slopes, particularly in a gully south of the existing Alliance RoW and on the bottom portions of the valley slope. Slides on portions of the east approach slope constrain route options in some areas. The west approach slope is lower (45 m) and has moderate slopes. A route close to the existing Alliance Pipeline would be difficult since this pipeline is located on a ridge on the east approach slope with gullies both south and north. A route close to the existing Peace Pipeline farther north would also be difficult due to a ridge on the east side of the valley. The ground conditions across the valley have also been found to be extremely difficult during past construction due to loose/soft water saturated sediments which have caved during trench construction. The proposed route is south of the gully south of the Alliance route, on the south side of an existing lease at the crest of the east approach slope. Based on ground reconnaissance, the preferred location diverges from the Alliance Pipeline toward the west and on the west side of the river would be approximately 430 m south. The east approach slope appeared to be stable overall, but has steep slope segments where bedrock outcrops occur on the lower part of the valley slope. Some areas of local slides. The route would cross the valley bottom in an area of apparently shallower muskeg than farther north and would end on an eroded terrace with shallow sandstone bedrock west of the river. There was very shallow soil creep over shallow bedrock on the terrace fronts on the west side of the valley. Alberta Research Council (1976b) suggests that bedrock is at an elevation of 850 m (2800 ft), which would be close to crest elevations of the approach slopes, indicating that most of creek channel may be eroded in bedrock. Bedrock outcrops were found on the lower third of the east approach slope and bedrock directly underlies the bench on the west side of the valley. Bedrock geology (Hamilton et al, 1999): Underlain by Upper Paskapoo Formation as above. While not shown on available published mapping, the deposits in the valley bottom consist of organics (muskeg) over extensive areas	removed. Local slides would require grading out. Trench blocks, probably some with drains, and cross berms would be required on the east approach slope. There are some areas of soft ground across the valley bottom which would be difficult, but length of soft ground appeared shorter than previous pipeline routes to the north. There would be grading, including bedrock, on the terrace fronts on the west side of the river. Further investigation and review of the approach slopes and valley bottom conditions is recommended during detailed design. Comprehensive ground and surface water control will be required in this area. There have been sedimentation problems in the past along the Iosegun River valley. Valley bottom: Crossing of approximately 400 m of muskeg will be required. Past experience indicates soft/loose water saturated ground conditions. Suitable construction planning for possible low bearing capacity, particularly adjacent to trench. **Open Cut Crossing**: Feasible on a preliminary basis but may require special techniques depending on results of further investigations.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		overlying soft or loose water saturated silt, sand and clay. There is a small channel close to the toe of the slope. On the west side of the valley, there is a higher terrace that is underlain by shallow glaciofluvial sediments overlying sandstone bedrock.	
259.3	290.3	Transitions to parallel Alliance Pipeline at KP 262.3. Parallels Highway 43 and Alliance Pipeline RoW west to KP 267.7. Crosses to north side of Alliance Pipeline. West of KP 267.4, route parallels Alliance Pipeline RoW north of Smoke Lake. Surficial Geology (St. Onge, 1966). Mainly till and hummocky till deposits on the uplands. Local small shallow muskeg areas in occasional closed depressions and along small streams. GEM terrain mapping indicated similar conditions except for glaciolacustrine sediments near KP 277 and some areas to west. Bedrock geology (Hamilton et al, 1999): Upper Paskapoo Formation as above and Lower Paskapoo Formation toward the west (similar to Upper Paskapoo Formation). Pawlowicz and Fenton (1995b) suggest that bedrock may be shallow in parts of the segment, although no areas of bedrock outcrop are shown on St. Onge (1966). Alberta Research Council (1976b) suggests that bedrock may be shallow across much of area.	No geotechnical concerns identified. See comments above regarding blasting in Paskapoo Formation, if it is encountered. KP 274.4 and KP 275.0: Tributaries to Iosegun Lake. Small streams, near flat ground. Preliminary indication from drilling investigations is that local deposits consist of glaciolacustrine clay over clay till. There was a harder zone that may be ice rafted bedrock. On a preliminary basis, directional drilling or conventional trenched crossing methods (open cut or isolated) could be considered from a geotechnical point-of-view.
290.3	291.8	**Little Smoky River – KP 291.0** Parallel to north side of Alliance RoW. East approach slope is approximately 45 m high. Back channel near toe of east approach slope. The route runs down a broad ridge. The meander pattern at the toe of the east slope is different from upstream and downstream, possibly due to slide activity. At the route location, the terraces appear to be due to deposition and erosion. Moderately deep-seated slides occur upstream and downstream of crossing location along east approach slope. No indication was found of active movements on the ground and based on LiDAR for the east approach slope. The west approach slope is higher (at least 75 m) with a steep area on the upper third of the slope. Old deep-seated slide blocks on the slope. Some tree bends and pistol butted trees but it was not clear from ground reconnaissance whether very small creep movements may be occurring or whether there is local groundwater piping into old slide	**Stability Conditions** Crossing is considered to be the best available from a geotechnical point-of-view in this general area. The east approach slope is buttressed by a wide terrace and the slope appears to be underlain by erosional/depositional terraces. Old deep-seated slides on west approach slope. The terrace is narrower at the toe of the west slope and there are prominent old slide blocks running across the slope. There has been a recent active slide to the south where the stream undercut the slope. There were some tree bends along route, but most of the bends appear to be due to local piping or other soil movements rather than recent deep-seated slide movements.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		tension cracks. The route has a bend at the crest of the west approach slope. Regional review suggests that slopes in the area are subject to deep-seated slide movements, probably including slides in both valley fill and bedrock, particularly when the slopes are undercut by active stream erosion. Recent (last 50 years) slightly accelerated movements of an old slide south of the crossing on the west side of the river due to undercutting of the north edge of the slide by lateral erosion. Side scarps of the slide above the laterally eroding meander appear to be close to the south of the proposed route on LiDAR. <u>Surficial geology</u>: Published mapping has not been located. Aerial reconnaissance and ground reconnaissance on the east side suggests sliding in the valley fills which appear to include high plastic glacial till and glaciolacustrine sediments. Due to widespread sliding, most of the deposits in the valley are technically colluvium. The river has migrated back and forth across the valley bottom resulting in alluvium with some areas of muskeg in old oxbows. Alberta Research Council (1976b) suggests that bedrock is at an elevation of 853 m (2800 ft) (close to crests of approach slopes) indicating that most of creek channel may be eroded in bedrock. Shale bedrock exposures were seen along the creek. <u>Bedrock geology</u> (Hamilton et al, 1999): Underlain by Lower Paskapoo Formation as above. The bottom of the valley may be close to the underlying Scollard Formation (grey feldspathic sandstone, dark grey bentonitic mudstone, thick coal beds, non-marine).	Although the river has been reasonably stable over the last approximately 50 years, the river has changed course in the past resulting in varying stability of slopes at varying locations along the river. Future changes in channel lateral erosion conditions may occur, possibly including a cut off meander downstream of the crossing. As noted, future changes in lateral erosion may trigger renewed movements at the crossing, particularly on the west approach slopes. Future mitigation may be required in the event of lateral erosion and should be allowed for in overall planning. Mitigation could possibly include river training, or drilling or other trenchless methods such as microtunnelling under the west approach slope. Further investigations and monitoring are recommended to check movement status of slopes. Further consideration of design and mitigative methods relative to stability conditions is anticipated during detailed design. Comprehensive ground and surface water control will be required. See comments above regarding blasting in Paskapoo Formation. Sandstone may be encountered on the upper parts of the slopes and would likely require blasting. Shale in the valley bottom may be softer and may be rippable in some areas, although in confined areas could also require blasting. **Open Cut Crossing**: Appears feasible based on geotechnical and channel morphology. Flows would be too high for flume or superflume isolation methods April to October.
291.8	302.3	Route follows existing Alliance Pipeline and other pipeline RoWs to west. Segment ends southeast of Crooked Lake. Rolling upland terrain. <u>Surficial geology</u>: Published mapping has not been located.	No geotechnical concerns identified.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Aerial reconnaissance suggests clay till deposits. GEM terrain mapping suggests undulating moraine with minor areas of glaciolacustrine and organic deposits. Bedrock geology: (Hamilton et al, 1999): Underlain by Lower Paskapoo Formation as above. Alberta Research Council (1976b) suggests that bedrock is deep through this area and unlikely to be exposed.	
302.3	317.3	Upland terrain with some areas of muskeg, a few crossings of old meltwater channels containing meandering streams and muskeg and a few stream crossings. Streams mostly tributary to Crooked Lake. Parallel to north side of Alliance and other pipeline RoWs. Deviates to north at KP 317.3. Surficial geology: Published mapping has not been located. Aerial reconnaissance suggests clay till deposits with minor glaciofluvial deposits. Several areas of muskeg as infills of terrain depressions along old glaciofluvial channels. GEM terrain mapping indicates undulating moraine, and glaciolacustrine and glaciofluvial sediments with scattered areas of organics. Bedrock geology: (Hamilton et al, 1999): Underlain by Lower Paskapoo Formation as above. Alberta Research Council (1976b) and suggests that bedrock may be close to exposure particularly across the ends of the ridges.	No geotechnical concerns identified. Ground and surface water control required. KP 305.3: Crossing of Nova Pipeline. KP 308.9 to KP 312.1: Deviates to run north of Alliance Pipeline KP 312.0, KP 314.0: Tributaries to Crooked River.
317.3	318.4	**Waskahigan River – KP 318.2** Meandering stream with tortuous meanders, numerous beaver dams. Crossing is in low terrain north (downstream) of where the river runs to the north in a deep steep-sided valley across a ridge south of the route. On east approach slope, route runs over 10 m high knob with slopes of about 15 to 20°. Route bends through about 60° across floodplain. West approach slope is stepped with a lower elevation terrace and a higher bench bordered by a gentle slope. Road crossing on west slope. Surficial geology: GEM terrain mapping indicates fluvial terrace deposits with organics in the center of the valley. Bedrock geology: (Hamilton et al, 1999): Underlain by Lower Paskapoo Formation as above. Alberta Research Council (1976b) suggests that bedrock may be close to exposure particularly across the ends of the ridges.	Area has not been reconnoitred on the ground. Interpretation of LiDAR did not indicate any stability problems. Ground reconnaissance recommended to check depths of organics relative to construction conditions including trench stability. **Open Cut Crossing**: Stream appears to be laterally mobile. Crossing may need to be deep (below scour depth) across a distance of 500 m or more. Local rerouting may be required to provide a straight crossing. Moving the crossing upstream might be advantageous in terms of reducing crossing length.
318.4	324.9	Upland ridged terrain. Some areas of locally steeper slopes. May be some areas close to rock outcrop.	Ground and surface water control on steeper slope segments.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Start of segment is north of Alliance Pipeline. Route rejoins Alliance Pipeline at KP 320.4. Two deviations around lease areas. Local infrastructure including several leases. <u>Surficial geology</u>: Published mapping has not been located. Aerial reconnaissance suggests clay till deposits. GEM terrain mapping indicates areas of moraine veneers over rock on steeper terrain around KP 323 with extensive areas of moraine and some glaciofluvial terraces. Occasional organics. <u>Bedrock geology:</u> (Hamilton et al, 1999): Underlain by Lower Paskapoo Formation as above. Alberta Research Council (1976b) and Pawlowicz and Fenton. (1995b) suggest that bedrock may be close to exposure particularly across the ends of the ridges.	
324.9	332.4	Lower terrain, rolling ridges across the route running toward the north. Small meandering streams between the ridges. Local infrastructure including several leases. <u>Surficial geology</u>: Published mapping has not been located. Aerial reconnaissance suggests clay till deposits. GEM terrain mapping indicates extensive areas of glaciofluvial deposits with some moraine and glaciolacustrine sediments east of approximately KP 329. KP 329 to KP 331, mostly till. To the west, mostly glaciofluvial and glaciolacustrine sediments with some moraine. Scattered organics throughout. <u>Bedrock geology:</u> (Hamilton et al, 1999): Underlain by Lower Paskapoo Formation as above. Alberta Research Council (1976b) and Pawlowicz and Fenton. (1995b) suggest that bedrock may be close to exposure particularly across the ends of the ridges.	Ground and surface water control required on slope segments.
332.4	336.2	On edge of ridge to south. Some areas of sideslope crossings of several incised creek valleys draining to north. Areas of muskeg. Local infrastructure including several leases, two pipelines and powerline. <u>Surficial geology</u>: Published mapping has not been located. Aerial reconnaissance suggests clay till and glaciolacustrine deposits with overlying muskeg in pockets and old meltwater channels. Bedrock may be close to surface on some ridges. GEM terrain mapping indicates similar deposits. <u>Bedrock geology:</u> (Hamilton et al, 1999): Underlain by Lower Paskapoo	Ground and surface water control required on slope segments. Steep gradient creeks will require suitable design scour cover over the pipelines.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Formation as above. Alberta Research Council (1976b) and Pawlowicz and Fenton. (1995b) suggest that bedrock may be close to exposure particularly across the ends of the ridges.	
336.2	339.6	**Deep Valley Creek – KP 338.8** Route on east approach slope is on a broad gradually descending ridge. No stability concerns or other geotechnical concerns identified from air. Two existing RoWs. There appeared to be room on both sides, but north side may be better for creek crossing. Creek crossing: Existing crossings appear to have been trenched. Gravel excavation on terrace on west side of creek north of existing RoWs with shallow water. Creek appears to be eroding very slightly toward the west on the north side and toward the east on the south side of the existing crossings. There is a minor back channel across a low elevation area of floodplain toward the south. West approach slope: Low and gently rolling. Surficial geology: Published mapping has not been located. Aerial reconnaissance suggests glaciofluvial deposits and possibly clay till or glaciolacustrine deposits. Recent alluvial deposits along channel and in low terraces. Bedrock geology: (Hamilton et al, 1999): Underlain by Lower Paskapoo Formation as above. Alberta Research Council (1976b) and Pawlowicz and Fenton. (1995b) do not indicate any large known buried channel.	Approach slopes: Ground and surface water control recommended. Overall: Favourable crossing with no major geotechnical issues found to date. Area should be reviewed on ground to check preliminary conclusions from air. **Open Cut Crossing**: Appears feasible from a geotechnical point-of-view. Isolation likely feasible over significant part of the year. A crossing on the north side may be slightly better geotechnically due to a shorter crossing and better conditions to the west. Consideration of lateral erosion and scour conditions will be required during detailed design.
339.6	340.6	Upland terrain north of Alliance and/or other pipelines. Surficial geology: Published mapping has not been located. Aerial reconnaissance suggests glaciofluvial deposits and possibly clay till or glaciolacustrine deposits. Recent alluvial deposits along channel and in low terraces. GEM terrain mapping suggests moraine. Bedrock geology: (Hamilton et al, 1999): Underlain by Lower Paskapoo Formation as above. Alberta Research Council (1976b) and Pawlowicz and Fenton. (1995b) do not indicate any large known buried channel.	No geotechnical concerns identified. Note that a crossing of the existing RoW and deviation to the south is shown on the proposed routing. This may not be required from a geotechnical point-of-view and should be further examined.
340.6	341.0	**Tributary to Deep Valley Creek – KP 340.8** Approximately 60 m deep valley with moderate slopes. No stability concerns identified from air on north side of existing RoWs. On west side of crossing, the creek meanders beside and below the existing RoWs on the south side and so a route on the north side of existing alignments is recommended. Subchannel on west side of crossing.	**Difficult area** From a geotechnical point-of-view, the preferred crossing is on the north side of the existing north RoW due to the lack of room and shallow sliding above the meander bends on the south side of the north existing RoW west of the creek crossing. Very tight area. Further ground reconnaissance

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Shallow sliding on the banks of the creek where it is undercutting the slope to the south of the crossing. Surficial geology: Published mapping has not been located. Aerial reconnaissance suggests clay till with possible glaciolacustrine and glaciolacustrine deposits. Recent alluvial deposits along channel and in low terraces. Bedrock geology: (Hamilton et al, 1999): Underlain by Lower Paskapoo Formation as above. Alberta Research Council (1976b) and Pawlowicz and Fenton. (1995b) do not indicate any large known buried channel.	of stability conditions and crossing area recommended. Ground and surface water control will be required on the approach slopes.
341.0	353.9	Upland terrain. Much of area is gently sloping toward north. Surficial geology: Published mapping has not been located. Aerial reconnaissance suggests clay till with occasional shallow and small muskegs. GEM terrain mapping suggests similar conditions. Bedrock geology: (Hamilton et al, 1999): Underlain by Lower Paskapoo Formation as above. Alberta Research Council (1976b) and Pawlowicz and Fenton. (1995b) indicate generally shallow rock which may be encountered across some ridged areas.	No geotechnical concerns identified.
353.9	358.4	Upland terrain sloping gently to moderately to the north. Crossings of three incised streams draining to the north to the Simonette River. Surficial geology: Published mapping has not been located. Aerial reconnaissance suggests clay till with occasional shallow and small muskegs. GEM terrain mapping suggests similar conditions with occasional glaciolacustrine sediments. Bedrock geology: (Hamilton et al, 1999): Underlain by Lower Paskapoo Formation as above. Alberta Research Council (1976b) and Pawlowicz and Fenton. (1995b) indicate generally shallow rock which may be encountered across some ridged areas.	Crossings of tributary stream valleys which are shallow on south sides and slightly deeper on north sides of existing RoW. Either side appeared acceptable from a geotechnical point-of-view based on preliminary reconnaissance. Tributary streams have relatively steep gradients. Pipeline cover should consider Further potential scour and downcutting conditions during detailed design.
358.4	359.6	**East approach slope to Simonette River**: Gently to moderately sloping terrain parallel to north side of existing Peace and Alliance RoWs. Road is a short distance to the south and west. Existing leases on southwest side of existing alignments. No slope stability concerns identified from the air at crossing, although slides at toes of both approach slopes north of crossing. Surficial geology (Andriashek, 1983): Locally derived thin ground moraine, moderately to exceedingly stony. Bedrock geology (McMechan and Dawson, 1995): Paskapoo Formation	On a preliminary basis, geotechnically preferred side is north side of existing RoWs to line up with preferred crossing area and to avoid existing infrastructure. Further geotechnical review of stability on ground is recommended. Ground and surface water control should be coordinated with existing controls on nearby RoWs.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		(Sandstone, cliff forming, sandstone, siltstone, mudstone, minor lenses of carbonaceous shale).	
359.6	360.1	**Simonette River Crossing – KP 360.0** Slightly meandering river. Old back channel on east side has been filled in at existing Alliance crossing but is still present on north side of existing crossings. On south side of existing crossings, there is a back channel on the west side. Floodplains extend to the toes of both slopes and both areas have had active erosion in the past. The bridge to south is changing erosion patterns to north. Existing crossings appear to have been trenched crossings. Bridge to the south is on piles with four piers in channel. River is eroding slowly toward the west at the existing crossings. Surficial geology (Andriashek, 1983): Uplands east of river: Locally derived thin ground till, moderately to exceedingly stony. In river valley: alluvial deposits. West of river: till. Bedrock geology (McMechan and Dawson, 1995): Paskapoo Formation (Sandstone, cliff forming, sandstone, siltstone, mudstone, minor lenses of carbonaceous shale). The mapping indicates that the Scollard Formation is not exposed in the bottom of the valley which is likely a major factor in the improved stability compared to farther north. Pawlowicz and Fenton (1995a) do not indicate any major preglacial channel at this location.	Geotechnically favourable location for a new crossing. Generally preferred side from a geotechnical point-of-view is on the north side of the existing RoWs to avoid the bridge which is located on the south side. Geotechnical ground reconnaissances and review of LiDAR are recommended. **Open Cut crossing**: Appears feasible from a geotechnical point-of-view. Isolation appears possible (Dec to Mar – dam and pump, July to Nov - fluming with superflume in summer). The new crossing would likely be longer than the existing crossings to allow for the back channel on the east side and for future lateral erosion toward both sides. Long crossing due to potential for lateral erosion and reoccupation of subchannels.
360.1	360.3	**West approach slope to Simonette River**: Route parallels north side of existing RoWs. Surficial geology (Andriashek, 1983): Till. GEM terrain mapping suggests glaciofluvial and fluvial sediments are also present. Bedrock geology (McMechan and Dawson, 1995): Paskapoo Formation (Sandstone, cliff forming, sandstone, siltstone, mudstone, minor lenses of carbonaceous shale).	No geotechnical concerns identified. Geotechnically favoured side is north side of existing RoWs to avoid road on south side and to line up with favoured crossing location. Ground and surface water control should be coordinated with existing controls on nearby RoWs.
360.3	365.3	Gently sloping upland terrain. Few areas of muskeg, but route bypasses most of them. Infrastructure along existing RoWs. Surficial geology (Andriashek, 1983): Glaciolacustrine silt and clay. Bedrock geology (McMechan and Dawson, 1995): Paskapoo Formation (Sandstone, cliff forming, sandstone, siltstone, mudstone, minor lenses of carbonaceous shale).	No geotechnical concerns identified.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
365.3	371.7	Slightly higher elevation terrain with ridges. Route parallel to existing RoWs bends around some areas of steeper topography. A few areas of moderate slopes. Flat bench east of Latornell River at end of segment. Surficial geology (Andriashek, 1983): Glaciofluvial and aeolian deposits with glaciofluvial sand to north. GEM terrain mapping indicates moraine rather than glaciofluvial materials. Scattered organic deposits. Bedrock geology (McMechan and Dawson, 1995): Upper Scollard Formation (Sandstone, siltstone, carbonaceous mudstone, coal interbedded with thin layers of claystone).	Ground and surface water control will be required on some slope segments.
371.7	372.2	**Latornell River – KP 372.0** Crossing is in upper reaches of river where it is narrow. Meander bend in valley bottom. Large amounts of debris in valley bottom with potential for jams to occur, potentially causing diversions of the stream. Valley is approximately 30 m deep with gentle to moderate slopes on each side. Route continues parallel to existing Alliance and Peace Pipeline RoWs. Existing road with bridge to the south. Crossing itself is narrow and straight. Surficial geology (Andriashek, 1983): Glaciofluvial sand near crest of east approach slope. Alluvial sediments along creek channel. Aeolian sands to west. GEM terrain mapping suggests that glaciolacustrine sediments may be present. Bedrock geology (McMechan and Dawson, 1995): Upper Scollard Formation (Sandstone, siltstone, carbonaceous mudstone, coal interbedded with thin layers of claystone).	**Difficult area** Meander bend of stream immediately south of Alliance RoW is a potential concern. Reconnaissance of area on ground and review of LiDAR are recommended. Ground and surface water control will be required on slopes. Crossing design will need to consider lateral erosion of meander bend to south and large amounts of debris that may result in significant diversions of the stream. See stability issue below.
372.2	378.2	Gently sloping to flat terrain. One area of muskeg a few hundred meters long. A few other smaller areas. Surficial geology (Andriashek, 1983): Aeolian sands. GEM terrain mapping suggests similar with areas of organic deposits and some glaciolacustrine deposits. Bedrock geology (McMechan and Dawson, 1995): Upper Scollard Formation (Sandstone, siltstone, carbonaceous mudstone, coal interbedded with thin layers of claystone).	**Slope stability**: KP 374.0 on east side of Alliance. Based on air reconnaissance, the present alignment may be too close to crest of an existing slide into the Latornell River. Potential solutions are to move the crossing or to cross for a short distance to the west side of Alliance. Review of LiDAR (when available) and further reconnaissance on ground are recommended.
378.2	382.1	Higher knob with moderate slopes. Rock may be shallow in some areas, although surficial mapping indicates deep sand as below. Gently sloping to flat terrain. One area of muskeg a few hundred meters	No geotechnical concerns identified. Ground and surface water control will be required on some slope segments.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		long. A few other smaller areas. Surficial geology (Andriashek, 1983): Glaciofluvial sand. GEM terrain mapping also suggests aeolian deposits. Bedrock geology (McMechan and Dawson, 1995): Upper Scollard Formation (Sandstone, siltstone, carbonaceous mudstone, coal interbedded with thin layers of claystone).	
382.1	390.4	Flat to locally undulating terrain. Occasional muskeg areas shown on mapping, but most of these appear to be missed by route. Infrastructure at various locations close to existing RoWs. Surficial geology (Andriashek, 1983): Glaciofluvial sand, aeolian sand deposits and mixed aeolian and glaciofluvial sand deposits. GEM terrain mapping is similar with some glaciolacustrine deposits. Bedrock geology (McMechan and Dawson, 1995): Upper Scollard Formation (Sandstone, siltstone, carbonaceous mudstone, coal interbedded with thin layers of claystone).	KP 383.4: One small kettle lake north of existing RoWs. Stream to north a short distance to west. Surface and possibly ground water control required on a few slope segments.
390.4	395.1	Slightly higher ridged terrain sloping to west. Road crossing near start of segment. To west, existing RoWs are uphill of the road separated by a strip of trees from the road. Surficial geology (Andriashek, 1983): Mixed aeolian and glaciofluvial sand deposits. GEM terrain mapping also indicates moraine and scattered organics. Bedrock geology (McMechan and Dawson, 1995): Upper Scollard Formation (Sandstone, siltstone, carbonaceous mudstone, coal interbedded with thin layers of claystone). Lower Scollard Formation underlies north half of segment (sandstone, siltstone, mudstone (grey to greenish grey), volcanic tuff).	No geotechnical concerns identified.
395.1	396.5	**Tributary to Smoky**: Short distance northeast of Alliance Pipeline or other pipeline crossings. Surficial geology (Andriashek, 1983): Mixed aeolian and glaciofluvial sand deposits. GEM terrain mapping indicates predominantly glaciolacustrine deposits on slopes. Bedrock geology (McMechan and Dawson, 1995): Lower Scollard Formation (sandstone, siltstone, mudstone (grey to greenish grey), volcanic tuff).	Stability conditions at proposed route appeared to be reasonably good, although there are slides in the general area. Ground and surface water required, likely including drains.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
396.5	400.6	Upland terrain sloping gently toward the Smoky River valley. Surficial geology (Andriashek, 1983): Mixed aeolian and glaciofluvial sand deposits. GEM terrain mapping predominantly morainal deposits with some organics. Bedrock geology (McMechan and Dawson, 1995): Upper Brazeau Formation (carbonaceous sandstone and siltstone, coal).	No geotechnical concerns identified.
Note on Bedrock Formations: From the Smoky River to west of the Wapiti River, (McMechan and Dawson, 1995) indicate the bedrock to be Upper and Lower Brazeau Formation (carbonaceous sandstone, siltstone and mudstone, with coal). Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds). The Wapiti Formation, which contains bentonitic high plastic clays, fits better with the prevailing stability conditions which include slides in bedrock and is also in the later dated reference. Therefore, the Hamilton et al (1999) interpretation has been quoted in this report in spite of being a smaller scale map.			
400.6	419.5	Upland terrain sloping gently toward the Smoky River valley. Route leaves Alliance RoW at KP 415.1, but mostly parallels other pipeline routes to crest of east approach slope to Smoky River at end of segment. Surficial geology (Andriashek, 1983): Mixed aeolian and glaciofluvial sand deposits. GEM terrain mapping also indicates glaciolacustrine deposits with some areas of organics. Bedrock geology Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds).	KP 404.1 to KP 404.6: Crossing of creek tributary to Smoky River. Moderately steep to steep slopes into small creek. Existing pipeline crossings to west. Local areas of moderately deep slides. Rev R route moved to the east away from an existing pipeline crossing to improve stability conditions.
419.5	420.3	**East approach slope to Smoky River**. Parallel to existing CNRL pipelines immediately to north. Breaching of a large beaver pond dam on the CNRL RoW will be required for construction. Steep terrace fronts near or steeper than 30° with two wide terraces. Surficial geology (Andriashek, 1983): Mixed aeolian and glaciofluvial sand deposits. Based on local observation, materials on slope are predominantly glaciofluvial sand or sand and gravel. Sandstone and shale exposed in steep slope segments near toe of slope and in a road about half way up slope. Bedrock geology Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds).	**Stability**: No major stability concerns identified on proposed route. Area to north of existing pipeline RoWs (opposite side to proposed route) has been eroded forming locally steep gullies and bowls (possible groundwater blow-off failures, but also appears to be stable. Moderately deep slides farther to the north where the slope has been undercut by the river. Also moderately deep slides to the south. Possible old slides on lower terrace front. Local grading of terrace fronts to lower angles will likely be necessary. Further investigation of slopes, possibly including monitoring, recommended.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
			Ground and surface water control will be required including trench blocks, drains (particularly near crest of slope) and cross berms. Surface water drainage will need to be coordinated with existing RoWs.
420.3	421.29	Fluvial terrace approximately 450 m wide on east side of Smoky River. West edge was being slowly eroded by river. Various infrastructure including roads, lease site and existing pipelines. Route south of existing pipeline RoWs. Sand or sand and gravel with extensive shallow areas of muskeg	Lateral erosion needs to be considered depending on crossing design. There has been significant lateral erosion at the existing pipeline crossings in the past. Route will need to go around a lease.
421.29	421.78	**Smoky River – KP 421.6** Wide terraces on both sides of the river. River is eroding to some extent both east and west at and near the crossing. Erosion is constrained to some degree by the road bridge approach fills approximately 1.2 km upstream of the crossing. Failure of these fills would allow much greater lateral erosion than at present. In the past, the river has eroded laterally over very significant distances both to the east and west. Preliminary route crosses under existing pipelines on the west edge of the present channel due to a bend in the pipeline and parallels the north side of the existing RoW on the west terrace. Bedrock geology Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds). Bedrock was exposed on the lower part of the east approach slope. Pawlowicz and Fenton (1995a) do not indicate any major preglacial channel at this location.	Lateral erosion needs to be considered during detailed design. **Open Cut crossing**: Appears feasible from a geotechnical point-of-view. The crossing would likely be relatively long (and probably longer than the existing crossings) to allow for lateral erosion which has been an issue for most of the installed crossings. Isolated crossing does not appear possible due to flow levels. **Directionally Drilled Crossing**: No detailed investigations to date. Conditions farther south at a previously considered crossing were apparently favourable. Existing information suggests that there may not be a deep preglacial channel in this area which would be a favourable condition. Assessed as feasible on a preliminary basis.
421.78	422.34	Terrace on west side of river 2 to 3 m above normal flow elevations in river. Has been subject to previous erosion/deposition relatively recently. Surficial geology (Andriashek, 1983): Glaciofluvial outwash gravel. Local observation suggests that the gravel has been reworked by relatively recent erosion. Bedrock geology Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic	Lateral erosion needs to be considered in overall crossing design.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds). Bedrock was not exposed on the terrace and but be at shallow depth although Pawlowicz and Fenton (1995a) do not indicate any major preglacial channel at this location. Note that Brazeau preglacial valley is located to the north; there is a possibility that there could be buried tributary channels in this general area.	
422.34	422.88	**West approach slope to Smoky River**. Route approximately parallels north side of existing RoW with two(?) pipelines along the edge of ridge to the north. Slope is about 70 m high at an overall angle of 9.5°. Route is just beyond apparent north edge of large deep-seated slide to the south. One very small crack 10 mm wide found on south side of adjacent RoW. At the toe of the slope there is abundant seepage, but no sign of a toe thrust. Trees along the existing RoW are straight. Surficial geology (Andriashek, 1983): Glaciofluvial terrace deposits. Surficial exposures of glaciofluvial sand and gravel. Gravel deposit on ridge to north with active pit. Bedrock geology Hamilton et al (1999): Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds). Bedrock was not exposed on the slope. Pawlowicz and Fenton (1995a) do not indicate any major preglacial channel at this location, although the Brazeau preglacial valley is located to the north.	North of deep-seated slide on main part of slope. A dogleg around the edge of a slide to the north may be required on the lower part of the slope subject to further investigations. If further work and information suggests a need to move farther from the slide, there is some additional room including a gravel pit to the north. Further investigations and monitoring of slope recommended. Ground and surface water control including drains and drained trench blocks will likely be required.
422.88	431.6	Route bends to follow existing seismic line and Nova Pipeline. KP 425 Major facility to south (Braaten Plant). Surficial geology (Andriashek, 1983): Glaciolacustrine silt and clay. Muskeg in local areas. GEM terrain mapping indicates similar with some moraine. Bedrock geology Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds).	KP 425 to KP 426: Very wet with muskeg. Area complicated by several pipelines, roads and other infrastructure. More detailed routing work on ground will be required during detailed design.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
431.6	432.1	**<u>Gold Creek – KP 431.9</u>** Incised meanders to a depth of approximately 30 m. Moderately steep slopes on both sides. Limited work room along creek. From the air there appeared to be some shallow slide activity. <u>Surficial geology</u> (Andriashek, 1983): Glaciolacustrine silt and clay on uplands. Colluvial materials on slopes. <u>Bedrock geology</u> Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds).	**Slope stability**: Further geotechnical review of slopes is recommended. Grading may be required. Most of spoil would likely have to be moved upslope. Surface and ground water control including trench blocks, cross berms and possibly drains.
432.1	434.9	Following existing pipeline across upland terrain. Some areas of muskeg nearby, but most of actual route appears to miss the major muskeg areas. <u>Surficial geology</u> (Andriashek, 1983): Glaciolacustrine silt and clay on uplands. Colluvial materials on slopes. <u>Bedrock geology</u> Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds).	No geotechnical concerns identified.
434.9	435.9	**<u>Big Mountain Creek – KP 435.3</u>** Crossing is southwest (upstream) of highway bridge. Incised meandering creek with slopes approximately 30 m high. Moderately steep slopes. Some evidence of shallow slope sliding, but existing crossing appear from air to have performed well. East approach slope: Existing pipeline runs directly upslope. West approach slope: Route is diagonally down slope. <u>Surficial geology</u> (Andriashek, 1983): Glaciolacustrine silt and clay on uplands. Colluvial materials on slopes. GEM terrain mapping similar. <u>Bedrock geology</u> Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds).	**Slope stability**: Further geotechnical review of slopes is recommended. Crossing may be too tight relative to existing road and may need to be moved, possibly to south. Crossing would be long since it is diagonal. Grading will be required. Most of spoil will likely have to be moved upslope. Ground and surface water control required. Surface and ground water control including trench blocks, cross berms and possibly drains.
435.9	445.7	Gently sloping terrain on north side of higher terrain to south. <u>Surficial geology</u> (Andriashek, 1983): Glaciolacustrine silt and clay on uplands. GEM Terrain mapping shows similar interpretation. <u>Bedrock geology</u> Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic	No geotechnical concerns identified.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds).	
445.7	446.1	**Bald Mountain Creek - KP 445.4**: Moderate slopes approximately 20 m high. Possible rock exposures near toes of slopes based on aerial reconnaissance. Surficial geology (Andriashek, 1983): Glaciolacustrine silt and clay. GEM Terrain mapping shows similar interpretation. Bedrock geology Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds).	Further geotechnical review of slopes is recommended. Ground and surface water control required. Surface and ground water control including trench blocks, cross berms and possibly drains.
446.1	459.7	Upland terrain. Gently rolling. Approx. KP 448.2 to KP 459.2: Generally along high grade road, existing pipeline parallel to road. In a few areas, the road deviates from the route which follows an existing cut line and/or existing pipeline RoW. Existing infrastructure. Surficial geology (Andriashek, 1983): Glaciolacustrine silt and clay on uplands. GEM Terrain mapping shows increasing moraine toward the west. Bedrock geology Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds).	KP 453.06 Wilson Creek. Mobile within flat valley bottom. Long crossing for size of creek. Confined at road crossings. Valley slopes are low, no stability issues identified from air. KP 458.1 Small incised creek. Crossing near road crossing. Shallow to moderately deep sliding of approach slopes. Will likely need to grade out. Ground and surface water control required on all approach slopes and on some upland slope areas.
459.7	470.1	Broad ridges across route, intervening small streams drain to south. Generally parallel to good road and existing pipeline. Several small stream crossings. Crossings in the eastern half tend to have muskeg along the valleys while those toward the west tend to be slightly incised. Surficial geology (Andriashek, 1983): Undifferentiated glaciofluvial and aeolian deposits. GEM mapping also suggests moraine and organic deposits. Bedrock geology Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic	No geotechnical concerns identified.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds).	
470.1	473.1	Gently sloping terrain on east side of Pinto Creek valley. Surficial geology (Andriashek, 1983: Glaciofluvial outwash sand. GEM terrain mapping suggests glaciolacustrine and morainal deposits on higher terrain outside of major valleys. Bedrock geology Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds).	**Stability** KP 469.9 - KP 470.3 Moderately deep-seated slide into meander bend of Pinto Creek close to south side of existing RoW. Preferred route is on the north. Route centerline will need to be moved slightly to the north during detailed design. Surface and ground water control including trench blocks, cross berms and possibly drains.
473.1	473.9	**Pinto Creek – KP 473.4** Surficial geology (Andriashek, 1983: East of creek valley crest: glaciofluvial outwash sand. Creek valley: Colluvial deposits on slopes and alluvial/glaciofluvial deposits along valley. Crest of west approach slope: Glaciolacustrine silt, minor clay. GEM terrain mapping also suggests glaciolacustrine deposits are present. Bedrock geology Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds).	**Stability** Some indications of stability issues. Stability of area should be further assessed on ground and using LiDAR. Surface and ground water control required. Graded materials should be moved to slope crests. Further geotechnical review of slopes is recommended. Surface and ground water control including trench blocks, cross berms and possibly drains.
473.9	476.9	Upland terrain parallel to existing road and pipeline. Surficial geology (Andriashek, 1983: Undifferentiated glaciofluvial and aeolian deposits. Local muskeg. GEM terrain mapping suggests large areas of glaciolacustrine deposits are present. Bedrock geology Hamilton et al (1999) indicate Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds).	No geotechnical concerns identified.
476.9	492.7	West of Pinto Creek to east of Wapiti River valley. Surficial geology (Andriashek, 1983): Glaciolacustrine silt and clay with overlying thin aeolian deposits. Toward the west, there is an increasing amount of glaciofluvial deposits overlain by aeolian deposits. Local muskeg. Bedrock geology (McMechan and Dawson, 1995): Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous	Near start of segment, possible shallow muskeg. KP 489 to KP 491 (approx.): Several ponds near alignment. Scattered small areas of muskeg.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		shale, scattered coal and bentonite beds.)	
492.7	493.15	**East approach slope to Wapiti River** Slope has at least two prominent terraces which appear to be erosional/depositional. Lower terrace front has possible discontinuous permafrost which is degrading and local shallow sliding. Bedrock is exposed along toe of slope (sandstone). Surficial geology (Andriashek, 1983): Undifferentiated aeolian and glaciofluvial deposits. Bedrock geology (Hamilton et al, 1995): Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds.)	No major sliding identified. Local shallow sloughing can be graded out. Steep terrace fronts will need to be graded out. Comprehensive ground and surface water control including trench blocks, cross berms and drains. Local permafrost was degrading rapidly and may be entirely gone by the time of construction.
493.15	493.3	**Wapiti River – KP 493.2** Near the proposed crossing, the Wapiti River flows through a deeply incised, meandering valley that is 80 to 120 m deep and 650 to 900 m wide at the valley crest. The large incised meander bends and associated steep parallel river valley slopes along the river form a series of interlocking upland terrain areas inside each meander loop (meander spurs) that constrain the route alignment through the valley area. The route crosses between two of the spurs. Specifically, on the east side, the route runs downhill across a series of erosional or depositional terraces. There is a wide terrace near the river. On the west side, the route runs up terraced slopes on the end of a spur and follows the spur to the west. There is one narrow area ("neck") at the west end of the spur where the route is constrained between a moderately deep slide apparently located on the lower part of the slope on the north side and a shallow to moderately deep slide on a steep rock slope to the south (discussed below). Surficial geology (Andriashek, 1983): Undifferentiated aeolian and glaciofluvial deposits. Glaciolacustrine and valley fill deposits at depth. Bedrock geology (Hamilton et al, 1995): Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds.)	**Open Cut Crossing**: Feasible. Isolation is not feasible due to flow levels. **Directionally Drilled Crossing**: Various directionally drilled alignments could be considered. One possibility would be between a low elevation terrace on the east side and a low elevation terrace on the west side. The "west" end would be on the north side of a ridge on the west side of the river due to the length of the crossing. Pipeline layout would be to the south and east and would require substantial grading of terrace fronts. Another potential crossing might be to drill between a low elevation terrace on the south side of the river and the uplands on the west. Major considerations for both holes would include the stratigraphy at depth.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Pawlowicz and Fenton (1995a) indicate a major west-east trending preglacial channel (Brazeau Channel) close to the crossing. Detailed review of local outcrop patterns suggests that this segment of the Wapiti River was eroded down through an area without a preglacial channel, that is, it is upstream of the area where the modern channel is close to a preglacial channel.	
493.3	494.7	**West approach slope and upland area of ridge**: Eastward pointing ridge between incised meander bends of river. Low elevation terrace at east end with point bar farther east. Several well defined narrow terraces with steep terrace fronts between. Surficial geology (Andriashek, 1983): Colluvium with glaciolacustrine clay (varved) to east. Local observation indicates glaciolacustrine clay and local glaciofluvial deposits on eroded terraces. Bedrock geology (Hamilton et al, 1995): Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds.)	No major stability issues identified. Shallow creep in some areas. Grading of route up front of ridge will be required. A route slightly on the sidehill to the north side of the ridge may assist with ground and surface water control. Surface and ground water control required including cross berms, trench blocks and drains.
494.7	495.0	**Narrow area (“neck) in ridge at edge of uplands.** On south side, apparent shallow slides in rock exposed on steep slopes down to Wapiti River and colluvium. On north side, apparent moderately deep-seated slide in valley fill glaciolacustrine clay.	**Stability** Preliminary field and office review suggests there is sufficient room between the slide crests. Further review recommended including additional ground reconnaissances including toe area of possible north slides. Potential mitigative measures if there is an issue include routing, surface and ground water control and (in the event of major problems), consideration of deep grading, directional drilling or other methods.
495.0	516.8	West of Wapiti River and north of Calahoo Lake. Upland rolling terrain rising toward the west. Several shallow valleys draining toward the north. Surficial geology (Andriashek, 1983): East half of segment: glaciolacustrine silt and clay overlain by thin aeolian deposits derived from the underlying silt and clay farther west. The west half of the segment is underlain by glacial till. Aerial reconnaissance indicated scattered muskegs, some of which	BC/Alberta Border at KP 516.6 approx. Scattered muskegs, particularly in the eastern half of segment. 496.9 old meltwater channel

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		were estimated to be greater than 1 to 1.5 m deep. GEM terrain mapping indicates similar conditions. Bedrock geology (McMechan and Dawson, 1995): (McMechan and Dawson, 1995): Upper Wapiti Formation (equivalent to Horseshoe Canyon Formation, grey feldspathic sandstone, grey bentonitic mudstone and carbonaceous shale, scattered coal and bentonite beds.)	
516.8	531.7	Upland area with terrain tending to rise toward the west. Surficial geology (Maxwell 1976a) East of Hiding Creek (KP 517.9): predominantly glaciofluvial sand and gravel with glaciofluvial and alluvial terraces near creek. Scattered areas of muskeg. To west to end of segment, terrain rises and is underlain by glacial till with frequent glaciofluvial deposits with occasional small meltwater channels. Scattered areas of muskeg throughout the segment; however, it may be possible to miss many of these areas. Bedrock Geology (GSC Open File 630, 1979): Wapiti Formation. Gently folded with folding and dips tending to increase toward west. Conglomerate, sandstone, carbonaceous shale, coal. Based on previous work, this formation contains high plastic clays and/or bentonitic clays in this area and is potentially subject to deep-seated sliding where exposed on high slopes.	Hiding Creek (KP 517.9) has an extensive area of muskeg in the valley estimated visually to be at least 1.5 m deep.
531.7	532.4	**South Redwillow River – KP 531.9** Confined and straight channel upstream, meander downstream. Crossing in tight area. Rock on east side. Might also occur on west side but not seen. Narrow valley with limited work room. The river is misfit in an old glaciofluvial meltwater channel. Surficial geology (Maxwell 1976a) East approach slope was mapped as till blanket over bedrock with glaciofluvial sediments a short distance to the east. Valley bottom is underlain by glaciofluvial sediments and organics likely overlying the materials to the east and west. The west approach slope (flat) is underlain by glaciofluvial veneers overlying till mantles. Aerial reconnaissance indicated extensive peat (muskeg) deposits across the valley bottom and beyond to the west. The Redwillow valley was a major glaciofluvial outwash channel. Bedrock geology (GSC Open File 630, 1979): Wapiti Formation. Gently folded with folding and dips tending to increase toward west. Conglomerate, sandstone, carbonaceous shale, coal. Based on previous work, this formation contains high plastic clays and/or	**Open Cut Crossing**: Appears feasible from a geotechnical point-of-view. Lateral erosion conditions also need to be considered. Isolation appears possible under winter conditions.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		bentonitic clays in this area and is potentially subject to deep-seated sliding where exposed on high slopes.	
532.4	546.5	Terrain rises to the west. The route runs south of Squaw Mountain near the end of the segment. At the end of the segment, the route runs down locally moderately steep slopes to Redwillow River valley. Surficial geology (Maxwell 1976a): Glacial till with frequent glaciofluvial deposits and occasional small meltwater channels. Scattered areas of muskeg throughout the segment; however, it may be possible to miss many of these areas. GEM terrain mapping had similar deposits. Bedrock geology (GSC Open File 630, 1979 and Kilby and Johnston, 1988a): Mostly Wapiti Formation. Gently folded with folding and dips tending to increase toward west. South of Squaw Mountain and to the west, the route crosses the first major thrust faults in the foothills. Bedrock is folded and faulted due to thrust faults over the last half of the segment. Bedrock may be shallow toward the end of the segment. Existing shale borrow pit near end of segment.	Bedrock is expected to be close to surface over west half of segment. Sandstone would require blasting if encountered. Some shale may also require blasting. There are two "tight" stream crossings near the end of the segment where extensive grading (including bedrock grading) will be required for large diameter pipelines. Areas underlain by Wapiti Formation may be more prone to stability issues, although none have been identified to date. Slope stability aspects should be checked in this area including consideration of the dip angles of the bedrock formations.
546.5	561.4	Along south side of Redwillow River valley and south of Stoney Lake. Route generally follows a ridge with some areas of flat valley bottom and frequent areas of sidehill including ridges. Surficial geology (Maxwell 1976b): East half of segment: Areas of organic blankets (muskeg) overlying glaciofluvial and fluvial deposits and minor till. West half: glacial till veneers and blankets over rock with lesser amounts of fluvial and glaciofluvial sand and gravel. Larger areas of organic blankets overlying glaciofluvial or fluvial sediments at end of segment. GEM terrain mapping had similar deposits. Bedrock geology (GSC Open File 630, 1979 and Kilby and Johnston, 1988a): Folded and thrust faulted Upper Cretaceous formations including Wapiti (see above), Puskwaskau (sandstone, siltstone), Badheart (sandstone, minor carbonaceous shale), Muskiki (pyritic shale), Cardium (sandstone, carbonaceous shale, conglomerate), Kaskapau (shale) and Dunvegan (sandstone, minor conglomerate, shale).	KP 557.6 Crossing of Spectra Energy Transmission Grizzly Pipeline ARD Potential: Note presence of Muskiki Formation near KP 548.0 (route may be south of where the formation pinches out in a thrust and fold) and approximately KP 551.7 to KP 552.9 based on published mapping.
561.4	566.2	Gently sloping to the north and west with several creek crossings including KP 561.5: Kinuseo Creek KP 564.9: Honeymoon Creek	Some of the creek crossings will require grading of the banks and/or riprap or other measures for bank restoration. There may be some areas of wet soil or muskeg. Conventional crossings preferred from a geotechnical

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		KP 566.0: Kinuseo Creek Wet soil conditions may occur at some of the creek crossings. Surficial geology (Maxwell 1976b): Organic veneer overlying fluvial sediments. Local observations indicate possibly substantial depths of glaciofluvial sediments which may be bouldery overlain by muskeg. GEM terrain mapping indicates large areas of glaciofluvial sediments which accords with field observations. Bedrock geology (GSC Open File 630, 1979 and Kilby and Johnston, 1988a): Gently folded Upper Cretaceous formations including Kaskapau Formation (shale), Dunvegan Formation (sandstone, minor conglomerate, shale) and Shaftesbury Formation (marine shale) at west end of segment. Local outcrops occur in general area, but much of area is covered with overburden.	point-of-view. Stream flow conditions would permit use of isolation techniques.
566.2	569.6	Parallel to north side of existing road on north side of Kinuseo Creek valley. High, steep bedrock ridge on north side of valley, route would sidehill across end of ridge. Surficial geology (Maxwell 1976b): Exposed rock ridge and colluvial veneers. GEM terrain mapping also indicated moraine veneers. Bedrock geology (GSC Open File 630, 1979 and Kilby and Johnston, 1988a): Tightly folded Lower Cretaceous formations including Boulder Creek (massive conglomerate, sandstone, shale and coal), Hulcross (marine shale, weak), Gates (conglomerate, shale, sandstone and coal), Moosebar (marine shale), Gething (conglomerate, shale, sandstone and coal), Cadomin (massive pebble to cobble conglomerate) and Minnes (thinly bedded sandstone, shale and coal).	**Difficult sidehill area**. Graded RoW should be kept as narrow as possible to reduce heights of cuts. Rapidly varying conditions likely in areas of sidehill cuts. Local stability conditions including shallow veneers over bedrock should be checked. Blasting: Almost all of the rock formations will require blasting. The conglomerate in several of the formations, and in the Cadomin Formation in particular, is known to be extremely strong and abrasive, resulting in expensive drilling. The Cadomin Formation is typically only 100 to 200 m thick and may be encountered near KP 561.8 to KP 562.0 (approx.). From KP 565.8 to KP 569.0 (approx) bedrock will be dipping toward the south at angles of 50 to 70°. The stability of cut slopes in this area (and any other areas with similar bedrock dip conditions) should be reviewed in the field. Other areas of local topping or sliding on joints should also be reviewed geotechnically in the field.
569.6	577.6	Benched to strongly ridged terrain. Surficial geology (Maxwell 1976b): Glaciolacustrine mantles, till veneers and gullied glaciofluvial veneers and blankets all overlying ridged rock.	**Difficult area.** Rapidly varying conditions likely with sidehill cuts. Local stability conditions including shallow veneers over bedrock

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Local observation indicated that there are also large glaciofluvial fans in this area. The route may encounter the ends of some bedrock ridges. Bedrock geology (GSC Open File 630, 1979): Folded bedrock of Minnes Formation (thinly bedded sandstone, shale and coal).	should be checked. Some of bedrock may be rippable in cuts. Minnes Formation generally requires blasting in trenches. KP 575.15: Quintette Creek. Meandering creek, slightly incised meanders. Crossing is on an apparent alluvial fan. Long crossing. Lot of debris in channel. Area should be checked further relative to potential for avulsion. Preliminary observations from the air indicate a possibility that the creek might avulse to the west 200 m or more. A crossing farther upslope may be less favourable. KP 575.95 spring beside road.
577.6	579.5	Route runs uphill over a broad ridge north of the road due to lack of room along the road which is along the edge of Kinuseo Creek at the toe of a steep slope. Road has been partially washed out. Last 0.8 km of segment is on flat to gently sloping terrain. Surficial geology (Maxwell 1976b): Till and colluvial veneers with minor glaciofluvial blankets overlying hummocky and ridged rock. Local observation indicated that bedrock will likely be encountered due to the extensive grading that will be required. Bedrock geology (GSC Open File 630, 1979 and Kilby and Johnston, 1988a): Folded bedrock of Minnes Formation (thinly bedded sandstone, shale and coal).	**Difficult grading area.** Extensive grading required. Bedrock dips are generally expected to be favourable (i.e. not tending to result in slope failures). Avoid the Cadomin conglomerate near end of segment if possible. Segment should be reviewed on ground from a geotechnical point-of-view. KP 577.9: Diagonal crossing of incised stream. Area should be checked further on ground and on LiDAR.
579.5	581.4	**Five Cabin Creek – 580.7** Alluvial fan on north side of Kinuseo Creek valley with steep rock ridge directly north of road beyond to west. The channel is high relative to the east and west edges of the fan and has been subject to past avulsion (channel switching). The channel morphology and recent deposits suggest that there have been recent high flow events over a width of 100 m or more (far in excess of the channel width) with local erosion and deposition to shallow depths. Avulsion channels over the last few tens of years may occupy an area at least 800 m across. The road fill was eroded during past events. Channel may be subject to debris flow events. Preliminary drilling data indicates a declining bedrock surface toward the west with coarse gravel and boulders overlying bedrock.	**Avulsion**: High likelihood of future avulsion, which could result in substantial erosion up to a few hundred meters from present channel. Avulsion and the potential for erosion should be considered during detailed design relative to the design crossing method. **Potential reroute**: There are conglomerate outcrops exposed on either side of the channel approximately 125 m north of the Rev R route. The stream appeared to be more tightly constrained in this area which may offer a shorter conventional crossing and a potential directionally drilled crossing. Further investigation and consideration of potential routes in this area is recommended. Avulsion

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Surficial geology (Maxwell 1976b): Alluvial and glaciofluvial fan. Local observations indicate that the fan is extremely bouldery. Bedrock geology (GSC Open File 630, 1979 and Kilby and Johnston, 1988a): Folded bedrock of Minnes Formation (thinly bedded sandstone, shale and coal).	would still be a consideration at the potential relocation area, but would be over a shorter lateral distance than farther downstream. Another reroute much farther upstream could also be considered. In this area, approach slope conditions may be more difficult; however, the creek channel is tightly constrained. **Open Cut Crossing**: Crossing would be long due to avulsion potential and deep with difficult groundwater conditions. The alternative of a crossing higher on the fan where the alluvial fan is narrower could also be considered. Isolation may be difficult due to high permeability of the fan and slope down the fan across the trench.
581.4	581.8	On edge of steep rock slopes to north. Surficial geology (Maxwell 1976b): Till and colluvial veneers, exposed rock. Bedrock geology (GSC Open File 630, 1979 and Kilby and Johnston, 1988a): Cadomin Formation (massive conglomerate) with Gates Formation (conglomerate, shale, sandstone and coal) directly to north. Thrust fault with drag folding. The bedrock conditions intersected (and the difficulty of the segment) will depend on the exact route relative to the bedrock topography.	**Difficult area** due to potential blasting in conglomerate and possibly slope stability. Detailed alignment should be reviewed geotechnically on the ground with respect to geotechnical conditions.
581.8	587.6	Glaciofluvial and possibly glaciolacustrine terraces with a few rock ridges. Surficial geology east end of segment (Maxwell 1976b): till and colluvial veneers. West end of segment (Maxwell 1976c): colluvial, glaciofluvial and till veneers over bedrock. GEM terrain mapping indicated predominantly glaciolacustrine and glaciofluvial terraces east of 584.1. To west, similar deposits with rock ridges. Bedrock geology (GSC Open File 630, 1979 and Kilby and Johnston, 1988b): East to west: Minnes Formation (thinly bedded sandstone, shale and coal), Fernie Formation (marine shale, weak, only a short segment), Whitehorse Formation (limestone, dolomite, minor sandstone, siltstone, gypsum.	Route is generally located on low areas.
587.6	588.5	**Kinuseo Creek – 588.1** Alluvial fan or terraces on east side bordered by prominent rock ridges. On west side, coalescent alluvial fans with glaciofluvial terraces,	**Lateral erosion:** Geotechnical conditions, in particular the potential for lateral erosion will need to be considered during detailed design. Also a meander to the east of the

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		probably buried rock ridges. Rock ridges farther to the west. Creek flows to north through narrow canyon north of study area. Surficial geology (Maxwell 1976c): Glaciofluvial and fluvial terrace and fan. Local observations indicate very bouldery material near surface. Bedrock geology (GSC Open File 630, 1979 and Kilby and Johnston, 1988b) East of crossing: Minnes Formation (thinly bedded sandstone, shale and coal), under creek and immediately to the west: Fernie Formation (marine shale, weak, only a short segment), to the west: Whitehorse Formation (limestone, dolomite, minor sandstone, siltstone, gypsum.	crossing is close to the south of the pipeline route and should be further examined relative to crossing design. **Open Cut Crossing**: Feasible, but may be deep long crossing due to potential for lateral erosion (requires further investigation). A route higher on the fan where the stream is more constrained could be investigated. However, the approach slopes into this area would be more difficult and might involve substantial cuts. Further work is recommended during detailed design.
588.5	596.9	Route runs west toward Murray River. Monkman Provincial Park to the south. Surficial geology (Maxwell 1976c): Colluvial veneers and blankets. Local observation suggests large glaciofluvial terraces east of KP 591.7. These are shown on GEM terrain mapping that also suggests morainal veneers over bedrock ridges to the north. Bedrock geology (GSC Open File 630, 1979) Strongly folded Whitehorse Formation (limestone, dolomite, minor sandstone, siltstone, gypsum. Fold axes control orientations of local valleys and streams. A portion of the route west of approximately KP 592.0 will be parallel to the local fold structure (i.e.., dips into or out of cut slopes).	Check local stability conditions where bedrock structure is parallel or close to parallel to grade cuts. Potential for local karstic conditions, although no karst has been identified to date in area. KP 595.9: Incised stream. Local grading including pulling back approach slopes may be required.
596.9	597.25	**Tributary to Murray River**. Moderate to steep approach slopes into and out of creek. Glaciofluvial materials along channel. Bedrock controlled valley with shallow colluvium and till on both slopes. Surficial geology (Maxwell 1976c): Colluvial veneers and blankets. GEM terrain mapping also indicated glaciofluvial materials along channel in accordance with local observation. Bedrock geology (GSC Open File 630, 1979) Strongly folded Whitehorse Formation (limestone, dolomite, minor sandstone, siltstone, gypsum. Fold axes control orientations of local valleys and streams	Further ground reconnaissance required to finalize design. Pulling back of slopes likely required. Ground water control including cross berms, trench blocks and drains.
597.25	598.4	Upland ridge east of Murray River bounded by the river to the west and a parallel tributary approximately 1 km to the east. The ridge extends up to approximately 100 m above the river elevation. The top is rolling and	Locally appreciable bedrock grading in ridged topography.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		is the site of a recent logging cut block. Nearby drilling investigations indicate limestone which may vary from intensely jointed to massive. Shallow till.	
598.4	598.8	**Murray River – KP 598.6** River valley is controlled by bedrock structure. The east approach slope varies up to 35° or more depending on location. The river channel is less than 100 m wide. The west approach slope is also steep with slopes on the lower part of up to 35° and flatter slopes higher up. The route on the west approach slope is constrained by the park to the south and a steep cliff and gully to the north. Rev R route runs slightly to the north down moderate slopes to the east side of the river. The directionally drilled option would be farther south. Surficial geology (Maxwell 1976c): Fluvial and colluvial veneers. Local observations suggest variable depths of colluvium and till on the approach slopes to the river with some local till. On the west approach slope, a borehole on the bench approximately 40 m above the river encountered sand overlying till to a depth of 8 m overlying limestone. Local observations and drilling several kilometres downstream of the crossing have encountered very thick (up to 60 m) deposits of collapsible silts and weak high plastic clay. The deposits at the crossing location are expected to be thinner and may not be collapsible, but the depth to the bedrock valley bottom is not known. Bedrock geology (GSC Open File 630, 1979) Strongly folded Whitehorse Formation (limestone, dolomite, minor sandstone, siltstone, gypsum. On the west side of the river, limestone, dolomite, cherty sandstone and chert of the Rundle, Hanington, Belcourt and Ranger Canyon Formations. Banff Formation (brown siltstone, limestone and shale) might also be encountered. Fold axes approximately parallel to the river valley. A thrust fault (western boundary of the Whitehorse Formation) is indicated west of the river.	**Directionally Drilled Crossing**: Not feasible due to lack of area for drag section layout (deep ravines on east side and steep slopes on west side. The directionally drilled crossing alignment evaluated is located south of the aerial crossing (Rev. R) alignment. Large topographic elevation changes would make it difficult to fit the crossing into the geometry. The apparent presence of a major fault on the west side is a potential concern. The potential presence of cherty rock types is a concern since these rock types are highly abrasive and very tough potentially resulting in high bit wear. Preliminary results of drilling indicate relatively low rock quality in some zones which could lead to stability problems in the directional hole. Overall, from a geological point of view, this is considered to be a difficult directional drill hole. From a geometry point of view, not feasible due to lack of drag section layout area as noted. **Aerial crossing**: An aerial is a viable alternative from a geotechnical point-of-view. The potential crossing location would be on the Rev. R alignment starting from or north of a rock bench on the east side to a piled foundation into bedrock (?) on the west side. Shoofly access would be required on both sides of the river down the steep slopes, which appears feasible. A buried riprap berm may be required to control lateral erosion depending on the location of the west end of the crossing. **Open Cut Crossing**: An open cut crossing on or near the aerial crossing alignment would be viable from a geotechnical point-of-view subject to hydrotechnical and other aspects. Lateral erosion protection may be required on the west side depending on location. Scour depths may be appreciable at the crossing location immediately downstream of a mid-channel island. Isolation would not be possible due to flow volumes at most times of the year. Superflume isolation might be marginally possible in late

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
			winter but would likely not be practical. **Karst**: The presence of limestone in the area raises the potential for karst, which has been identified a few kilometres north and south of area. No karst has been identified along the proposed route. Slopes would require ground and surface water control including trench blocks, drains and cross berms. Detailed design of other surface water aspects in connection with shoofly access would also be required.
598.8	600.6	West approach slope to Murray River The west approach slope extends with wide benches up to approximately 250 m above the river. Steep slopes between the benches. The route is constrained by steep slopes and cliffs to the north with a deeply incised stream gully and to the south by Monkman Park. A switchbacked shoofly would be required on the west approach slope for access. Surficial and bedrock geology as above.	**Difficult area**: Shoofly access to aerial crossing would switchback down slope north of alignment. The route for a shoofly would be constrained by the topography plus the presence of the Provincial Park boundary to the south. Some areas of relatively high cuts and fills along shoofly access. Preliminary design indicates that there is sufficient room for a shoofly and the cuts for the pipeline RoW; but the area is tight. Detailed engineering design required. Ground and surface water control including cross berms, trench blocks and drains. French drains may be required. Design of drainage control measures for access shoo fly also required.
600.6	601.9	West of Murray River Moderate slope with one area of steep slopes that runs downhill from divide between Murray River and Hook Creek. The band of steep bedrock slopes is further constrained by steep slopes to the north and a bluff to the south. Moderate to steep slope downhill to edge of Hook Creek valley. <u>Surficial geology</u> (Maxwell 1976c): Colluvial veneers, hummocky and ridged exposed rock. Local observation suggests there may be appreciable till or possibly glaciofluvial material along the route, particularly the western half of the segment. Rock may be encountered on the eastern half. <u>Bedrock geology</u> (GSC Open File 630, 1979): As per western end of segment above. West end of segment is in the Banff Formation (brown	**Difficult route** with areas of moderate to steep slopes. Cuts requited along alignment. Separate shoofly access may be required. Groundwater and surface water control will be required on the slopes and shoofly.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		siltstone, limestone and shale).	
601.9	603.5	**<u>Hook Creek (KP 602.5) and valley</u>** Hook Creek runs southeast down a valley controlled by bedrock structure to join Imperial Creek, a tributary of the Murray River. The crossing is located close to a junction between a braided section of channel to the north and the alluvial fan to the south. Farther upstream, the creek is eroding extensively in a canyon which is contributing surficial materials that are augmenting the braiding process. West of the proposed alignment, Imperial Creek may erode laterally in the future into the lower stretches of Hook Creek, which limits the crossing location in a downstream direction. There are two higher elevation dry channels to the east. <u>Surficial geology</u> (Maxwell 1976c): Till blankets and veneers over rock. Local observation indicates that Hook Creek has a glaciofluvial and alluvial fan at the junction with Imperial Creek. There are glaciofluvial terraces along Imperial Creek and likely also glaciolacustrine deposits in this area. Glaciofluvial materials also occur along Hook Creek and in the lower stretches, bedrock ridges parallel to the creek have likely been buried in glaciofluvial materials with possible glaciolacustrine silts or clays overlying. <u>Bedrock geology</u> (GSC Open File 630, 1979): Banff Formation (brown siltstone, limestone and shale) east of Hook Creek. Besa River Formation (black shale) to the west. The contact is along a thrust fault and associated drag fold that is close to the confluence of Hook Creek with Imperial Creek close south of the route.	**Lateral erosion**: Stream is tending to erode laterally to the west and further lateral erosion is likely to occur. Further review on the ground is recommended. **Directionally Drilled Crossing**: Potentially difficult directionally drilled crossing due to confluence of glaciofluvial meltwater channels potentially containing boulders along both Hook Creek and the adjacent Imperial Creek valley. An additional consideration is the location and characteristics of a thrust fault zone if the directional drill would extend down into bedrock, as appears to be likely. Further investigation would be required. **Open Cut Crossing**: Appears to be feasible from a geotechnical point-of-view. The detailed crossing design would need to consider the possibility of lateral erosion to the west near the downstream end of the braided channel section. Isolation feasible most times of year depending on geometry of crossing and nature of substrate sediments. Possible ARD prone materials have been identified to the west and might occur in this area as well.
603.5	610.1	Strongly ridged terrain and steep topography north of Imperial Creek. The route cuts across a road that switchbacks around the ends of the bedrock ridges. <u>Surficial geology</u> (Maxwell 1976c): Till blankets and veneers over rock. Colluvial and till veneers, exposed rock. GEM Terrain mapping indicated similar materials. <u>Bedrock geology</u> (GSC Open File 630, 1979): Route crosses a thrust fault and associated drag fold forming an anticline. Devonian formations include the Palliser (limestone, dolomite, minor shale), Perdrix (black shale) Formations and Lower Ordovician formations include the Monkman (orthoquartzite) and Chusina (limestone, argillaceous limestone, minor shale).	**Difficult Area** Rough ground with locally extensive grading in rock. Fill placement for work side will likely be required. Geotechnical considerations will include: • On edge of potential avalanche prone terrain. More severe conditions are to west of this segment. • Stability of rock cuts, particularly in areas where strike is parallel to cut. • Stability of fills on locally steep cross slopes. • Drilling and blasting in quartzite bedrock (extremely strong, hard and tough). • Ground and surface water control will be required.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
			Detailed geotechnical review of area in field is recommended. **ARD** prone rock formations have been identified in parts of this area in outcrop in Imperial Creek (Besa River Formation). See further details in ARD reports.
610.1	617.7	West along north side of Imperial Creek valley and tributary valley. <u>Surficial geology</u> (Maxwell 1976c): Colluvial and till veneers. Local observation from the air indicates there may be thicker till deposits and some glaciofluvial deposits with areas of shallower rock along the toe of the steeper rock slope and occasional rock spurs. <u>Bedrock geology</u> (GSC Open File 630, 1979): Folded and thrust faulted rock. Lower Ordovician Chusina (limestone, some argillaceous, and minor shale) and Monkman (quartzite) Formations and Middle Ordovician Skoki Formation (oncolitic dolomite, minor sandstone).	KP 611.6 to KP 613.6: Close below ends of **avalanche paths**. While avalanches may not reach route (needs to be checked), there appears to be a potential for diversion of stream flows toward the west, resulting in higher flows in some channels. KP 615.6 to KP 616.6 (approx): Possible **alluvial fan**. Further checks on avulsion potential recommended. KP 616.4: **Avalanche** path above route. **Difficult drilling and blasting**: Drilling and blasting in possible quartzite bedrock (extremely strong, hard and tough). Ground and surface water control including cross berms, trench blocks and drains will be required.
617.7	620.15	Route crosses Imperial Creek to south side of valley and runs up a series of steep rock steps. Gently sloping terrain between rock steps. There may be shallow perched groundwater in some areas. <u>Surficial geology</u> (Maxwell 1976c): Till and colluvial blankets or veneers, ridged rock. Aerial observation indicates that the area is very wet with sloping wet organic deposits. <u>Bedrock geology</u> (GSC Open File 630, 1979): Upper Cambrian Lynx Formation (limestone, dolomite), Lower Ordovician Monkman Formation (quartzite) and Chusina (limestone, argillaceous limestone, minor shale), Middle Ordovician Skoki Formation (oncolitic dolomite, minor sandstone).	KP 618.25: Crossing of Imperial Creek **Difficult Area** Available time period for working will be reduced by weather conditions and snow. Difficult access. Rock blasting. Grading on rock steps may be required. Shoofly requirements have not been defined in detail. Potentially wet conditions with shallow perched groundwater on underlying rock and potentially shallow slide conditions. Further ground work to define conditions and design required. Ground and surface water control including cross berms, trench blocks and drains will be required. KP 620.15: Avalanche path to south of route. Appears unlikely to reach route, but checks of possible stream diversions will be required.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
620.15	623.45	Route runs on gently to moderately sloping terrain just east of pass. Route crosses back and forth across small drainage in valley and also crosses drainages from sides of valley. Rock controlled terrain overlain by variable depths of till. Terrain may be wet with perched groundwater on underlying rock. Some areas of muskeg. Surficial geology (Maxwell 1976c): Till and colluvial blankets or veneers, ridged rock. Aerial observation indicates that the area is very wet with sloping wet organic deposits. Bedrock geology (GSC Open File 630, 1979): Upper Cambrian Lynx Formation (limestone, dolomite), Lower Ordovician Monkman Formation (quartzite) and Chusina (limestone, argillaceous limestone, minor shale), Middle Ordovician Skoki Formation (oncolitic dolomite, minor sandstone).	**Difficult Area** KP 623.45 Unnamed pass through Rocky Mountains Elevation at pass = 1430 m (4700 ft) approx. Available time period for working will be reduced by weather conditions and snow. KP 623.65: Route in this segment crosses below or across **avalanche** tracks which will need to be considered in the safety plan and work execution. Large amount of blasting and grade rock. An additional problem is the sloping terrain with organic cover which may be prone to shallow sliding. Detailed geotechnical plans and recommendations for this area based on further ground reconnaissance will be required. Shallow soil covers may be fine grained and wet, resulting in difficult sedimentation control. Blasting and extensive grading will be required in a number of hard formations including very hard, tough and extremely strong quartzite. Ground and surface water control including cross berms, trench blocks and drains will be required.
623.45	633.65	High elevation gently to locally moderately sloping terrain with numerous small stream crossings. Some areas of steep rock or till ridges. Local observation indicates that there are numerous springs along the valley bottom, many of which have raised bogs in their immediate vicinity. Most of these appear to be missed by the route. Surficial geology (Maxwell, 1976d) Colluvial and till veneers with areas of exposed rock. To south and west within segment, areas of thicker till blankets and silty glaciolacustrine deposits overlain by muskeg. Deposits and bedrock modified by active frost processes. Local observations indicate extensive areas of muskeg with frequent till ridges. The route runs on the edge or beside the larger muskeg areas wherever possible. Bedrock geology (GSC Open File 630, 1979): Lower Ordovician Chusina (limestone, argillaceous limestone, minor shale), Upper Cambrian Lynx Formation (limestone, dolomite), Middle Cambrian	KP 627.75, KP 628.45 and KP 630.05 (approx) Crossings of tributaries to and **Missinka River** (upper reaches). Streams may be subject to high flows or possibly debris flows. **Difficult Area** Available time period for working will be reduced by weather conditions and snow. Avalanche zones exist on valley walls but are typically distant from route. Sloping terrain with organic cover and shallow perched surface water. Portions of area are subject to solifluction and related frost activity. Shallow organics and soil veneers may be subject to sliding over sloped rock. The best routes appear to be on the sideslopes and till ridges. Detailed geotechnical plans and recommendations for this area based on further ground reconnaissance are

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Snake Indian, Titkana and Arctomys Formations (dolomitic siltstone, dolomitic shale), Lower Cambrian Mahto (quartzite), Mural (limestone) and McNaughton (quartzite, pebble conglomerate, siltstone, argillite and shale) Formations; and Hadrynian Upper Miette Group (argillite and siltstone with minor sandstone).	recommended. Springs along the valley bottom may be related to groundwater flow conditions in limestone; however, no karstic conditions have been identified in this area in work to date. Springs and associated raised bog areas should be avoided. Shallow groundwater and other areas of springs may be intercepted during the work. Blasting and extensive grading will be required in a number of hard formations including very hard, tough and extremely strong quartzite.
633.65	636.55	Sidehill on north side of tributary to Missinka River. Generally favourable bedrock conditions with bedrock dipping into slope. Shallow bedrock with colluvium or till overlying. Some areas of fine grained soils identified throughout the lower reaches of the valley. <u>Surficial geology</u> (Maxwell, 1976d) Colluvial and till veneers with areas of exposed rock. To south and west within segment, areas of thicker till blankets and silty glaciolacustrine deposits overlain by muskeg. Deposits and bedrock modified by active frost processes. <u>Bedrock geology</u> (GSC Open File 630, 1979): Lower Ordovician Chusina (limestone, argillaceous limestone, minor shale), Upper Cambrian Lynx Formation (limestone, dolomite), Middle Cambrian Snake Indian, Titkana and Arctomys Formations (dolomitic siltstone, dolomitic shale), Lower Cambrian Mahto (quartzite), Mural (limestone) and McNaughton (quartzite, pebble conglomerate, siltstone, argillite and shale) Formations; and Hadrynian Upper Miette Group (argillite and siltstone with minor sandstone).	**Difficult area** Streams may be subject to high flow or debris flow. KP 633.75 (approx.): Route sidehills up steep rock ridge “step” approximately 60 m high. Sidehill rock cut required. Further work to design the cut will be required. KP 634.75 to KP 635.15: Approach slope to creek crossing with steep steps. Steep areas will need to be cut back. Shoofly may be required. Further field reconnaissance and detailed design work will be required. KP 637.55 Route crosses to south side of tributary. Stream may be subject to high flows or debris flows. Ground and surface water control including cross berms, trench blocks and drains.
636.55	641.25	South side of small tributary stream. Gentle to locally moderate cross slopes. First clear cut is crossed about KP 638.45. <u>Surficial geology</u> (Maxwell, 1976e): Colluvial veneers, few areas of till blankets and local glaciofluvial deposits. <u>Bedrock geology</u> (GSC Open File 630, 1979): Hadrynian Upper Miette	KP 636.45: Stream crossing. Alluvial fan. Lateral stability of stream on fan will need to be further considered. Stream may be subject to high flow events or debris flows, which will need to be considered in crossing design. Ground and surface water control including cross berms, trench blocks and drains.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Group (argillite and siltstone with minor sandstone) and Byng Formation (dolomite and minor shale). Local observation indicates extensive outcrops of limestone, indicating that the outcrop boundaries on some mapping may be misleading	
641.25	641.55	**<u>Missinka River (East) – KP 641.35</u>** Crossing of Missinka River. Broad valley with river incised up to 100 m into floor of valley. There is a canyon upslope of the crossing. Boulders along the channel have iron staining. Nearby logging cut blocks. <u>Surficial geology</u> (Maxwell, 1976e) Colluvial and till blankets. Limited local observations suggest there may be glaciolacustrine deposits overlying till and/or valley fill deposits potentially including bouldery materials. Local observation and experience indicates that local tills are soft with poor trafficability and tend to slump in cuts, depending on angle. <u>Bedrock geology</u> (GSC Open File 630, 1979): Hadrynian Middle Miette Group (pebble conglomerate, argillite, diamictite. Tightly folded. Pyrite visible in veins. Potential ARD considerations.	**Open Cut Crossing**: Appears feasible from a geotechnical point-of-view. Potential sedimentation and erosion issues on approach slopes in glaciolacustrine materials may require specific design measures. Isolation using dam and pump, flume or superflume (depending on time of year) feasible with respect to flows. However, bouldery substrates may be challenging for isolation and may make isolation not practical. **ARD**: Schist and hyalite in general area, particularly to the west, contain pyrite and may be acid generating (ARD). Past experience with working on the silt tills in this area indicates that they are soft and working pads constructed or quarried rock may be required. Rock from local quarries and grade or trench rock may be subject to ARD considerations. Further detailed engineering and planning will be required. **Local stability**: Stability of cuts and trafficability of road surfaces in glaciolacustrine silt and soft silt till has been a problem in past.
641.55	645.45	Tight bend, crossing of tributary stream. Route located on east side of main valley on rolling flat terrain incised with tributary stream channels. Limited local observation suggests glaciolacustrine deposits left on slopes. Deposits formed behind the main ice lobe in the Parsnip River valley. Difficult cuts, weak soils, lateral groundwater flow issues. <u>Surficial geology</u> (Maxwell, 1976e) Colluvial and till blankets on both sides of canyon. Local observation and experience indicates that local tills are soft with poor trafficability and tend to slump in cuts, depending on angle.	**Difficult area, local stability problems** Weak glaciolacustrine soils (silt and clay). Potential groundwater issues. Stability of logging road cuts and fills, trafficability of road surface have both been problems in past. Further evaluation and ground reconnaissance. KP 644.05 Crossing of stream. Creek may be subject to debris flows; but, crossing is located away from steep terrain and most of the material would likely deposit higher up to the east. However, relatively high flows could occur

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Bedrock geology (GSC Open File 630, 1979): Hadrynian Middle Miette Group (pebble conglomerate, argillite, diamictite. Tightly folded.	and will need to be considered during detailed design. Ground and surface water control required. **ARD**: Schist and hyalite in general area contains pyrite and may be acid generating (ARD). Past experience with working on the silt tills and glaciolacustrine soils in this area indicates that they are soft and working pads constructed or quarried rock may be required. Rock from local quarries and grade or trench rock may be subject to ARD considerations.
645.45	646.15	**Missinka River (West) – KP 646.05** Crossing of Missinka River. East approach slope is moderately to gently sloping up to 50 m high. No major slope on west. Limited local observations suggest glaciolacustrine deposits on slopes. Deposits formed behind the main ice lobe in the Parsnip River valley. Potentially difficult cuts, weak soils, lateral groundwater flow issues. Surficial geology (Maxwell, 1976e) Colluvial and till blankets on both sides of canyon. Bedrock geology (GSC Open File 630, 1979): Hadrynian Middle Miette Group (pebble conglomerate, argillite, diamictite. Tightly folded.	**Open Cut Crossing**: Appears feasible from a geotechnical point-of-view. Potential sedimentation and erosion issues on approach slopes in glaciolacustrine materials may require specific design measures. Isolation using dam and pump, flume or superflume (depending on time of year) feasible with respect to flows. However, bouldery substrates may be challenging for isolation and may make isolation not practical. **ARD**: Schist and hyalite in general area contains pyrite and may be acid generating (ARD). Past experience with working on the silt tills and glaciolacustrine soils in this area indicates that they are soft and working pads constructed or quarried rock may be required. Rock from local quarries and grade or trench rock may be subject to ARD considerations.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
646.15	666.55	North side of Missinka River valley. Route is mostly near toe of slope. Most of route parallels an existing logging road. Surficial geology (Maxwell, 1976e): Along lower part of valley slopes: colluvial and till veneers and blankets with periodic alluvial fans. Along valley bottom: glaciofluvial deposits overlain by discontinuous to scattered and often thin areas of muskeg. There are local reports of glaciolacustrine materials in this area that have resulted in stability concerns along the existing logging roads. Bedrock geology (GSC Open File 630, 1979): Hadrynian Middle Miette Group (pebble conglomerate, argillite, diamictite). Tightly folded, decreasing folding to the west.	**Difficult Area** Past experience with working on the silt tills and glaciolacustrine soils in this area indicates that they are soft and working pads constructed or quarried rock may be required in some areas. Ground and surface water control required. **Debris Flows, high stream flows and alluvial fans**: Streams along the side of the valley that originate in alpine areas and that have a large headwater tributary area may be subject to debris flow and/or unusually high flows as a result of warm rain on wet snow events. These streams also, in some cases, may have alluvial fans. Further consideration of these streams during detailed design will be required. Streams potentially subject to these mechanisms include KP 644.85, KP 653.05, KP 654.15, KP 657.45, KP 659.25, KP 660.05, KP 663.15, KP 664.35, KP 665.95.
666.55	671.05	Route leaves Missinka Valley and runs across sideslopes north of river to Parsnip River crossing. Surficial geology (Watt and Lord, 1975): Till and colluvium blankets and veneers. Occasional areas of glaciofluvial fans. Toward end of segment, increased amounts of glaciolacustrine sediments and organic blankets. Local observations suggest that stability concerns have occurred in the glaciolacustrine sediments. Bedrock geology (Armstrong et al., 1969) Misinchinka Group chlorite and sericite schist, phyllite, schistose grit, quartz-pebble conglomerate and Misinchinka Group black slate, greywacke, minor quartzite, conglomerate (adjacent to east end of crossing).	Areas of sideslope including where the route is close to parallel to local streams should be examined from a geotechnical point of view. Drilling and blasting in some of the harder rock types such as quartzite would be difficult. Ground and surface water control required.
671.05	672.85	**Parsnip River – KP 670.95** Wide flat valley bottom (part of Rocky Mountain Trench). River channel is toward the east side. Swamp and muskeg terrain with shallow groundwater across valley bottom to west. Surficial geology (Watt and Lord, 1975): Organic blanket over glaciofluvial and fluvial sediments. Depth not known. Tipper (1971a) indicates that as early as Eocene time, the flow of the Fraser River ran	**Directionally Drilled Crossing**: Considerations include the possible presence of quartzite in the rock formations and the possible presence of boulders in the overburden materials (the valley has carried major flows since Eocene or Tertiary time and was a major glaciofluvial meltwater channel at the end of glaciation). Limited area on north side of river for establishing an entry point. A significant

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		north along the Parsnip River and other valleys. He refers to sediments that may be Tertiary or older. Bedrock geology (Armstrong et al., 1969) Misinchinka Group black slate, greywacke, minor quartzite, conglomerate (adjacent to east end of crossing). At west end Lower Cambrian dolomite, limestone, quartzite and slate. No faults are indicated within the portion of the valley that would be crossed by the directional drill; however, a regional fault is shown at the west side of the valley, west of the end of the proposed crossing. Bedrock appears to have been tightly folded, but overall competency is not known.	cut may be required. Further geotechnical investigations to establish depth and nature of overburden, the competency of the bedrock and the distribution of quartzite and other potentially problematic rock types would be required. **Open Cut Crossing**: Appears feasible from a geotechnical point-of-view. Trench stability on the west side of the valley may be an issue – further investigation would be required. Due to high flows, isolation would not be possible at any time of the year. **Difficult area on west side of valley** Difficult terrain conditions in low lying areas. Shallow groundwater and ponded surface water. Muskeg and glaciolacustrine silts and clays with sand seams. There have been cut stability concerns along the local logging roads. Trench and cut stability may be a problem. Further geotechnical review recommended. **Lateral erosion**: Potential for lateral erosion to the west needs to be further evaluated in terms of lengths of crossings.
672.85	687.05	Across ridge and knob to rejoin existing road along north side of creek valley. Moderate slopes. Local observations: KP 673.35 to KP 674.35, KP 675.35 to KP 676.35: Frequent areas of muskeg overlying wet glaciolacustrine silt and clay with sand seams. Surficial geology (Watt and Lord, 1975): Glaciolacustrine veneers over till and rock. GEM terrain mapping indicates moraine and areas of organics. Bedrock geology (Armstrong et al., 1969) Lower Cambrian dolomite, limestone, quartzite and slate and Cambrian Kechika Group (limestone, calcareous siltstone and calcareous schist).	Areas of rock cut. Several stream crossings, some of which may have small alluvial fans. Detailed consideration of grading requirements in wet and organic soils will be required in some areas. Ground and surface water control required. Cross berms and possibly erosion matting, mulching or other measures may be required.
687.05	697.95	North side of valley tributary to Chuchinka Creek Surficial geology (Watt and Lord, 1975) and Tipper (1971b): Glaciolacustrine veneers and blankets over till along lower parts of slopes. In bottom of valley, glaciofluvial and fluvial sediments. GEM terrain mapping also indicates morainal veneers. Bedrock geology (Armstrong et al., 1969): Lower Cambrian dolomite, limestone, quartzite and slate; Cambrian Kechika Group (limestone,	**Difficult terrain conditions in low lying areas**. Shallow groundwater and ponded surface water. Muskeg and glaciolacustrine silts and clays with sand seams. There have been cut stability concerns along the local logging roads. Trench and cut stability may be a problem. Geotechnical ground review recommended.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		calcareous siltstone and calcareous schist); Sandpile Group (limestone, dolomite, quartzite, sandstone) and Triassic argillite, greywacke and shaley limestone.	Cross slopes will need more detailed design. Also consideration of shallow slides on crests of cuts in steep areas (potential sedimentation and erosion issue). Bedrock requiring blasting will likely be encountered in cuts and trench. Ground and surface water control required. Cross berms and possibly erosion matting, mulching or other measures may be required. KP 695.15 – KP 697.15: Crosses several small creeks that may have alluvial fans. Further consideration of crossing designs may be required during detailed design.
697.95	710.15	Route runs across hummocky to knobby terrain with intervening valleys. Frequent rock drumlins and drumlins. Grain of land runs across route indicating that appreciable grading will be required. Local observation suggests wet surficial deposits in low areas consisting of glaciolacustrine silt and clay with sand interbeds. There have been cut and fill stability concerns along nearby logging roads. <u>Surficial geology</u> (Watt and Lord, 1975 and Tipper, 1971): Over higher ridges and knobs, till veneers and blankets with local exposed rock. In lower areas, thicker glacial till overlain in some areas by glaciolacustrine veneers to blankets. <u>Bedrock geology</u> (Armstrong et al., 1969): Lower Cambrian dolomite, limestone, quartzite and slate; Cambrian Kechika Group (limestone, calcareous siltstone and calcareous schist); Sandpile Group (limestone, dolomite, quartzite, sandstone) and Triassic argillite, greywacke and shaley limestone.	Locally extensive grading for large diameter pipelines. Rock will generally require blasting. Note the presence of quartzite. **Difficult terrain conditions in low lying areas**. Shallow groundwater and ponded surface water. Muskeg and glaciolacustrine silts and clays with sand seams. There have been cut stability concerns along the local logging roads. Trench and cut stability may be a problem. Geotechnical ground review recommended. Ground and surface water control required. Cross berms and possibly erosion matting, mulching or other measures may be required. KP 703.05: Chuchinka Creek crossing.
710.15	710.95	**Angusmac Creek – KP 710.45** Steep east approach slope with angles on the upper part of the slope up to 15 to 20° above the logging road, steepening to 25 to 30° below the road over vertical distances of 10 to 15 m (all estimated). Note that the logging road has been reconstructed higher up on the slope than shown on the 50K maps. The previous road appears to have been eroded out during past lateral erosion events. Rock is exposed along the toe of the east slope and at intervals along the logging road higher up on the east slope. The rock is fine grained metamorphics; no pyrite seen.	Depending on the crossing method, a substantial throughcut will be required below the present logging road to reduce slopes down to the creek along the RoW. There was room for this cut between the crest of the slope and the road. The cut will likely be in rock. Ground and surface water control required including trench blocks (possibly with drain) at crest of slope and at intervals down slope. **Open Cut Crossing**: Appears feasible from a geotechnical point of view. A relatively long crossing would be required

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		The creek valley is wide and flat with rock exposures along the toe of the east approach slope. Banks are typically 2 to 3 m above the creek, with some higher banks. The creek is meandering with some cut-off meanders along the valley. The crossing is located on a meander loop projecting toward the west. There is a small high level channel across the back of the meander bend along the toe of the east approach slope that apparently flows at high water. The west approach slope is lower and the route is diagonally up the slope. <u>Surficial geology</u> (Watt and Lord, 1975 and Tipper, 1971b): Organic blanket (muskeg) over glaciofluvial sediments. The Angusmac valley likely carried glaciofluvial flows and the possibility of an incised channel into bedrock cannot be ruled out at the time of writing. GEM terrain mapping and local observations indicate morainal deposits over shallow bedrock on east side and a glaciofluvial or fluvial terrace on the west side. <u>Bedrock geology</u> (Armstrong et al., 1969): Slide Mountain Group basaltic pillow lavas, andesite, pyroclastic rocks, argillite, chert, greywacke. Fault bounded basin west of main McLeod Lake Fault.	due to lateral erosion conditions. Setback of the east sagbend into the toe of the slope and/or provision of riprap or other erosion protection may be required. Isolation is possible relative to flows for most of year.
710.95	713.85	Hummocky to knobby and/or ridged terrain with intervening valleys. Frequent rock drumlins and drumlins. Grain of land runs across pipeline route. Local observation suggests wet surficial deposits in low areas consisting of glaciolacustrine silt and clay with sand interbeds. There have been cut and fill stability concerns along nearby logging roads. <u>Surficial geology</u> (Watt and Lord, 1975 and Tipper, 1971): Over higher ridges and knobs, till veneers and blankets with local exposed rock. In lower areas, thicker glacial till overlain in some areas by glaciolacustrine veneers to blankets. <u>Bedrock geology</u> (Armstrong et al., 1969): Lower Cambrian dolomite, limestone, quartzite and slate; Cambrian Kechika Group (limestone, calcareous siltstone and calcareous schist); Sandpile Group (limestone, dolomite, quartzite, sandstone) and Triassic argillite, greywacke and shaley limestone. At end of segment, route crosses east part of McLeod Fault, a major regional fault zone. On the west side of fault, there are poor exposures	Locally extensive grading for large diameter pipelines. Rock will generally require blasting. Note the presence of quartzite. **Difficult terrain conditions in low lying areas**. Shallow groundwater and ponded surface water. Muskeg and glaciolacustrine silts and clays with sand seams. There have been cut stability concerns along the local logging roads. Trench and cut stability may be a problem. Geotechnical ground review recommended. Ground and surface water control required. Cross berms and possibly erosion matting, mulching or other measures may be required.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		of granitoid gneiss, micaceous, garnetiferous chloritic schists, pegmatite and small bodies of granodiorite.	
713.85	717.95	Route runs north of the Town of Bear Lake. Flat terrain. Typical local conditions are loose aeolian sand or fluvial gravel 5 to 10 m thick over clay till, gravelly. Frequent areas of muskeg. Surficial geology (Watt and Lord, 1975 and Tipper, 1971b): Organic blanket (muskeg) over glaciofluvial sediments. GEM terrain mapping indicates moraine with glaciofluvial terraces at west end of segment. Bedrock geology (Armstrong et al., 1969): Slide Mountain Group basaltic pillow lavas, andesite, pyroclastic rocks, argillite, chert, greywacke. Fault bounded basin west of main McLeod Lake Fault.	Near surface groundwater.
717.95	718.95	**Crooked River – KP 718.25** Wet terrain underlain by muskeg. Route follows slightly higher ground where possible including an old winter road on east side of crossing. Surficial geology (Watt and Lord, 1975 and Tipper, 1971): Organic blanket (muskeg) over glaciofluvial sediments. Layers of boulders have been encountered in some of the sediments in this general area. Artesian conditions found in BH CR06-02. Bedrock geology (Armstrong et al., 1969): Slide Mountain Group basaltic pillow lavas, andesite, pyroclastic rocks, argillite, chert, greywacke. Fault bounded basin west of main McLeod Lake Fault. May be splays of McLeod Lake Fault. Local observations suggest deep granular deposits with surficial muskeg. Bedrock may be very deep.	**Open Cut Crossing**: Appears feasible from a geotechnical point-of-view but isolation may be very difficult due to presence of muskeg. Flows appear to be low enough for isolation except in April and May. Muskeg conditions in area may make construction difficult. Potential concerns could include trench stability. Artesian water pressures were encountered below trench depth in one investigation hole.
718.95	747.95	Ridged and drumlinoid terrain. Some ridges have rock exposed on crests of ridges. Surficial geology (Tipper, 1971): Ridged terrain, frequent drumlins and occasional rock drumlins. Glaciofluvial outwash channels with sand and gravel deposits. GEM terrain mapping indicates morainal deposits of variable depth. Bedrock geology (Armstrong et al., 1969) Rock mostly not exposed. Granitoid gneiss, micaceous, garnetiferous chloritic schists, pegmatite. Small bodies of granodiorite over a short area near center of segment.	Route runs across grain of drumlins, thus requiring significant grading for large diameter pipelines.
747.95	748.8	**Muskeg River – KP 748.1** Muskeg east of crossing. Likely glaciofluvial sediments possibly overlying till. Bedrock may be very deep.	**Open Cut Crossing**: Appears feasible from a geotechnical point-of-view but muskeg east of crossing will need to be considered in more detail including depth and trench

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Low banks in a wide valley. Channel is gently curved toward the west and may be migrating slowly toward the west.	stability. Isolation would be possible most of the time based on flows except for April and May.
748.8	761.0	Ridged and drumlinoid terrain. Some ridges have rock exposed on crests of ridges. Surficial Geology (Tipper, 1971): Ridged terrain, frequent drumlins. Glaciofluvial outwash channels with sand and gravel deposits. Bedrock is likely deep.	Route runs across grain of drumlins, thus requiring significant grading for large diameter pipelines. Rock seen in the top of one drumlin near KP 752.4. KP 751.1: Crossing of Mossvale Creek
761.0	762.7	East approach slope to Salmon River valley. Sloping bench, gentle slopes down into river valley. Surficial Geology (Tipper, 1971): Ridged terrain, frequent drumlins. Glaciofluvial outwash channels with sand and gravel deposits. Bedrock is likely deep.	Surface and groundwater control required.
762.7	763.3	**Salmon River – KP 763.1** Banks are about 3 m high. The river has eroded laterally over the entire valley floor leaving old channels, oxbows and meander scars. There is a large amount of debris along the channel and future lateral migration is likely to occur. Surficial geology: Armstrong and Tipper (1948) indicate up to 5 m of clay overlying deeper sediments. Past drilling in other areas has encountered interbedded sand, clay and gravel containing variable quantities of cobbles and boulders. Bed of river was predominantly sand with some areas of cobbles and boulders. Local observation indicated thick deposits of loose to compact fine sand. The Salmon River was a major glaciofluvial outwash channel at the end of the last glaciation. The river tends to erode laterally and concerns have been experienced on other pipeline crossings installed using trenched methods.	**Lateral erosion**: The Salmon River is highly mobile and has eroded laterally over most of the valley bottom. Lateral erosion and scour will need to be considered during detailed design. **Open Cut Crossing**: Feasible from a geotechnical point-of-view, but may be a very long and potentially deep crossing due to lateral migration of river. The crossing would likely need to extend across the entire valley bottom. Isolation using superflume could be considered with respect to flow conditions from August through March.
763.3	763.5	**West approach slope to Salmon River** Slopes 15 to 25° over 70 m high. Shallow erosion draws on slope with deeper gullies near route. No stability issues identified during field reconnaissance at proposed crossing; however, there is some sliding to the south where the river is undercutting the slope. There is also a	Gullies on west slope will require further consideration in overall routing. Surface and ground water control required. Drains for trench blocks likely required. If shoofly is required, careful routing will be required due to

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		possible slide to the north near a meander bend of a tributary creek.	potential for sediment generation in surficial soils and areas of sliding to the south. Detailed consideration of routing required.
763.5	810.5	Rolling upland terrain. Surficial geology (Tipper, 1971): Drumlinized till plain. Local observations indicate several glaciofluvial meltwater channels likely with sand and gravel infill. Muskeg veneers to blankets in bottoms of valleys and some other closed depressions. 798.7 to 801.2: Moderate sidehill. Shallow till over rock.	Several small creek crossings. Some will require grading of approach slopes. Surface and ground water control required. KP 763.6 and KP 763.9: Diagonal crossings of two tributary valleys to Salmon River. Substantial grading due to diagonal crossings of incised channels. Ground and surface water control required. Drains likely required. KP 780.3 Tributary to Great Beaver Creek: Grading of steep approach slopes will be required. Surface and ground water control required.
810.5	817.0	Route bends to the north along the east side of the Salmon River-Necoslie River valley south of Fort St. James. The route is predominantly through fields with some areas of low brush. Surficial geology: Local observations, water well information and drilling at Stuart River suggest deep glaciolacustrine sediments overlying sand or sand and gravel at depth. The sediments are infilling a large glaciofluvial outwash channel occupying a wide valley. The glaciolacustrine sediments appear to be deeper than the veneers indicated in Plouffe, 1996a. Bedrock geology (Struik, 1998): Siltstone, siliceous argillite, ribbon chert, slate, siltstone, conglomerate, chert conglomerate. Plouffe (2000) indicates a major regional fault down the Stuart River valley a short distance east of the proposed crossing.	Areas of shallow groundwater. There may be drains in some of the fields. Further ground checks of local conditions recommended during detailed design. Ground and surface water control. Trench blocks may be required in some areas to prevent migration of shallow groundwater along trench.
816.9	817.8	**Necoslie River – KP 816.4** Meandering river incised relative to terrain on both sides. Forested areas on both sides of crossing. River occupies the eastern part of a very wide glaciofluvial channel. Local observation suggests a possibility of high plasticity glaciolacustrine deposits (correlated with the Stuart Lake deposits) overlying sand and gravel at depth. Aerial review suggests local sliding as a result of banks and slopes being undercut by meandering stream. Significant grading would likely be required for a	Ground and surface water control. Trench blocks may be required in some areas to prevent migration of shallow groundwater along trench. **Open Cut Crossing**: Feasible from a geotechnical point-of-view. Relative to the stream flows, isolation would be possible at most times of year except in April and May. Significant cuts may be required.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		trenched crossing in order to put the pipeline in stable soil under the slides. Further field examination required.	
817.8	821.0	Route runs across a very large former glaciofluvial channel. Mostly fields with some areas of low brush. Surficial geology (Plouffe, 1996a): Glaciolacustrine veneers and blankets. Material at depth is not indicated, but may be till or more likely glaciofluvial and glaciolacustrine sediments. Local observation indicates several small stream crossings and a few wet areas.	Local wet areas and areas of muskeg. There may be drains in some of the fields. Further ground checks of local conditions recommended during detailed design. Ground and surface water control. Trench blocks may be required in some areas to prevent migration of shallow groundwater along trench.
821.4	822.2	**Stuart River – KP 821.9** Crossing is located toward western side of a very large former glaciofluvial channel. The proposed route is located north of the apparent north ends of deep-seated slides that extend along both sides of the valley. East valley slope has deep gullies that appear to be dry based on aerial reconnaissance. These gullies may have been formed by glacial run-off during deglaciation. The main slope segment on the east side is about 30 m high with a very steep upper area (up to 30°) near the crest of the slope with most of the lower part of the slope at 6 to 9°. There is a gently sloping apron or bench about 150 m wide (width varies) at the toe of the slope. There is a moderately deep-seated slide on the lower terrace that apparently extends up to the crest of the upper terrace in a few areas. The west valley slope is terraced with two main terrace levels below the uplands. The lower terrace has variable widths but is generally narrow. The upper terrace also varies in width but is typically 150 m wide or more. Both terraces are rolling with variations in elevation. The terrace fronts are at angles of 30° or more. The overall slope height to the uplands is about 30 m. Surficial geology Local observations, water well information and drilling at Stuart River suggest deep glaciolacustrine sediments overlying sand or sand and gravel at depth. Based on projections from water wells and drill holes, the depths of glaciolacustrine material appear to extend from the uplands to well below the river channel, although there is some uncertainty and the possibility of gravel at higher elevations cannot be ruled out without drilling. The sediments are infilling a large glaciofluvial	**Stability**: A slide on the west side of the lower river terrace forms a significant constraint on crossing methods. A trenched crossing through the slide is not considered viable. Trenchless crossing methods should extend beyond the slide area. The stability of the upper parts of the slopes should be verified by ground reconnaissance. **Open Cut Crossing**: Not recommended due to stability concerns on lower terrace of west approach slope. **Directionally Drilled Crossing**: Viability will depend mainly on depth of the interface between the overlying glaciolacustrine clay and the underlying glaciofluvial sediments. Preliminary information indicates that there may be sufficient vertical room for an in-valley crossing but this will need to be further investigated during detailed design. **Other Trenchless Methods**: Appear to be viable subject to further investigation. Depth to gravel is an important issue.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		outwash channel occupying a wide valley. The glaciolacustrine sediments appear to be deeper than the veneers indicated in Plouffe, 1996a. Bedrock geology (Struik, 1998): Siltstone, siliceous argillite, ribbon chert, slate, siltstone, conglomerate, chert conglomerate.	
822.2	827.4	Flat to gently rolling terrain. Surficial geology: Local observations, water well information and drilling at Stuart River suggest deep glaciolacustrine sediments overlying sand or sand and gravel at depth. The sediments are infilling a large glaciofluvial outwash channel occupying a wide valley. The glaciolacustrine sediments appear to be deeper than the veneers indicated in Plouffe, 1996a. Scattered areas of muskeg. Bedrock geology (Struik, 1998) Siltstone, siliceous argillite, ribbon chert, slate, siltstone, conglomerate, chert conglomerate.	Some areas of muskeg. KP 825.5: Crossing of Pitka Creek.
827.4	830.4	Terrain rises. Ridged, with locally steep slopes, locally chaotic terrain, closed depressions (kettle holes). Surficial geology (Plouffe, 1996a): Sand and gravel ice contact deposits. Locally used as a source for aggregates. Locally called the eskers; eskers are present along the west edge of area and in other areas, but many of the ridges are a result of collapse of the formerly ice supported deposits. Bedrock geology (Struik, 1998): Eocene Endako and Ootsa Lake Groups andesite, basalt and associated volcanics.	Some areas of muskeg in kettle holes and on lower areas. Locally high or perched groundwater. Appreciable grading in sand and gravel depending on route across area. Surface and ground water control required.
830.4	841.6	Rolling to hummocky terrain. Surficial geology (Plouffe, 1996a): Mainly hummocky glacial till. Small meltwater channels with glaciofluvial materials throughout. Scattered areas of muskeg. Bedrock geology (Struik, 1998) Siltstone, siliceous argillite, ribbon chert, slate, siltstone, conglomerate, chert conglomerate.	Some areas of muskeg. Surface and ground water control required in local areas of steep terrain.
841.6	853.7	Terrain rises. Rolling to hummocky. Surficial geology (Plouffe, 1996a): Mainly hummocky glacial till veneers and blankets over shallow rock. Some areas of outcrop and scattered areas of muskeg. Bedrock geology (Struik, 1998): Eocene Endako and Ootsa Lake Groups andesite, basalt and associated volcanics.	Some areas of muskeg. Steep slope at end of segment should be examined geotechnically. No problems identified from aerial reconnaissance or on airphotos. Surface and ground water control required on slopes.
853.7	872.7	Mainly low elevation terrain along old glaciofluvial channels. Terrain rises toward west end of segment.	Some areas of muskeg. Surface and ground water control required on slopes.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Surficial geology (Plouffe, 1996a): Glaciofluvial terraces (sand and gravel), some kettle holes, scattered areas of muskeg, some eskers. Some areas of till toward the west.	
872.7	929.15	Rolling and ridged terrain east of Burns Lake. Congested at end of segment. Surficial geology (Plouffe, 1996b): Mainly glacial till veneers and blankets. Some areas of outcrop and scattered areas of muskeg. Bedrock geology (Rice, 1948) Endako Group volcanics and granodiorite and related intrusive rocks.	No major geotechnical concerns identified. Rock grading and rock trench across the crests of several ridges. Surface and ground water control required on slopes. Fill may need to be minimized on some cross slopes.
929.15	929.55	**Endako River – KP 929.3** between Decker Lake and Burns Lake. Congested area on east side with highway, various buildings and infrastructure and rail tracks along east side of channel. Surficial geology (Plouffe, 1996b): Deltaic sediments deposited as an alluvial and glaciofluvial fan and delta from the west side of the valley cutting the former lake in two. Sand and gravel overlying silt and clay. Till veneers over rock underlying valley walls east and west of crossing. Glaciofluvial terrace directly south of the crossing and there are likely glaciofluvial sediments at depth in the valley. Local observation indicates muskeg along both sides of the river. Bedrock geology (Rice, 1948): East side: Eocene conglomerate, sandstone and shale. West side (west of edge of valley): Jurassic or Cretaceous Hazelton Group (volcanics and minor sedimentary rocks).	**Directionally Drilled Crossing**: Preliminary drilling results indicate geological difficulties including boulders and gravel. Not favoured geotechnically. **Open Cut Crossing**: Feasible from a geotechnical point-of-view. The railway on the east side the channel and soft muskeg near the channel would need to be further considered. While flows are lower than the limits for isolation, isolation would require special methods due to the depth of the channel.
929.55	948.05	Upland terrain including most of east approach slope to Maxan Creek which in part is a regional ridge (see below). Terrain has strongly developed broad ridges running north-south. Surficial geology (Tipper, 1994 and Plouffe, 2000): Till veneer and blanket deposits over shallow rock with scattered areas of organics (muskeg) and small areas of glaciofluvial deposits. Thicker and more laterally continuous areas of organics in some larger valleys. Bedrock geology (Tipper, 1976) Eocene and Oligocene Buck Creek Volcanics (andesite, dacite, minor basalt).	KP 941.45: Gerow Creek: Probable glaciofluvial channel with sediments, although not mapped as such. **Some areas of moderate to steep slopes**. Ground and surface water control required on some steep slope segments.
948.05	948.25	**Maxan Creek – KP 948.05** Long gentle to moderate approach slope on east side. The stream valley bottom is about 250 m wide. East of the creek, conditions in the spruce cover appeared to be wet. The conditions at the creek channel itself may be a bit drier and the terrain on the west side is also drier. Creek channel appeared to be deep, about 5 to 10 m wide with a few	There are some areas of rilling on the east approach slope that should be avoided or mitigated. No stability problems identified from aerial reconnaissance on either approach slope. Sagbend locations will need to consider the width of the

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		beaver dams. Flowing very slowly. Gravel bars on the west side, meandering. Very gentle approach slope on west side with heavy forest cover. Surficial geology (Tipper, 1994 and Plouffe, 2000): Till veneer and blanket deposits over shallow rock with scattered areas of organics (muskeg) on approach slopes. Thicker and more laterally continuous areas of organics in lower part of valley probably overlying glaciofluvial deposits. Bedrock geology (Tipper, 1976) Eocene and Oligocene Buck Creek Volcanics (andesite, dacite, minor basalt)	meander band (perhaps 150 to 175 m) and the potential for lateral erosion (appeared to be low). Ground and surface water control on long east approach slope.
948.25	957.15	Upland terrain with strongly developed broad ridges running north-south and deeply incised valleys. Surficial geology (Tipper, 1994 and Plouffe, 2000): Till veneer and blanket deposits over shallow rock with scattered areas of organics (muskeg) and small areas of glaciofluvial deposits. Thicker and more laterally continuous areas of organics in some larger valleys. Bedrock geology (Tipper, 1976) Eocene and Oligocene Buck Creek Volcanics (andesite, dacite, minor basalt).	No geotechnical problems identified. Ground and surface water control on slopes.
957.15	960.25	South of Foxy Creek approximately parallel to existing road. Surficial geology: GEM terrain mapping indicates mostly till with a few areas of muskeg. Bedrock geology (Tipper, 1976): Goosly Volcanics, trachytic flows and sills.	An area of known ARD issues exists west of the route at Equity Silver Mine. No rock formations similar to those that are acid generating at Equity have been identified during ground reconnaissance work to date.
960.25	960.75	**Foxy Creek – KP 960.4** Creek flows toward the east in a valley with approach slopes sloping approximately 15°. The slope on the south side is part of a rounded ridge. The slope on the north side is approximately 40 m high. Surficial geology (Tipper, 1994): Glaciofluvial outwash sediments in outwash channel. Bedrock geology (Tipper, 1976): Buck Creek Volcanics (andesite, dacite, minor basalt).	An area of known ARD issues exists at Equity Silver Mine. No rock formations similar to those that are acid generating at Equity have been identified along the route during ground reconnaissance work to date. Ground and surface water control on slopes.
960.75	964.35	Upland area north of Foxy Creek, rolling to gently sloped terrain with occasional steep areas on upper parts of ridges. Local pockets of muskeg. Surficial geology (Tipper, 1994): Extensive glaciofluvial outwash sediments forming valley infill. Local observations indicate several	Local pockets of muskeg. Areas of rock outcrop on ridges and possibly a few creek crossings. Note: Route in part of this area would be affected by

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		steep areas of rock outcrop adjacent to route. GEM terrain mapping indicates till with scattered organics. Bedrock geology (Tipper, 1976): Buck Creek Volcanics (andesite, dacite, minor basalt).	reroute discussed above.
964.35	975.65	Upland terrain with two crossings of Foxy Creek. Surficial geology (Tipper, 1994): Extensive glaciofluvial outwash sediments forming valley infill. Local observations indicate several steep areas of rock outcrop adjacent to route. GEM terrain mapping indicates till with scattered organics. GEM terrain mapping indicates mostly till with some fluvial deposits along creeks. Bedrock geology (Tipper, 1976): Buck Creek Volcanics (andesite, dacite, minor basalt); Goosly Lake Volcanics (trachytic flows and sills); China Nose Breccias (glassy basaltic breccias, some water lain sediments).	KP 964.55 Crossing of Foxy Creek KP 966.95 Crossing of Foxy Creek Ground and surface water control on slopes.
975.65	985.1	Upland terrain. Several stream crossings, generally low to moderate slopes. Surficial geology (Tipper, 1994): Higher elevation terrain that may not have been glaciated during last glaciation (Fraser glaciation). Older glacial and glaciofluvial deposits. GEM terrain mapping indicated mostly till of variable depth. Glaciofluvial deposits toward end of segment. Bedrock geology (Tipper, 1976): Eocene and Oligocene Endako Group: Buck Creek Volcanics (andesite, dacite, minor basalt) and China Nose Breccias (glassy basaltic breccias, some water lain sediments).	Some areas of rock outcrop along crests of a few ridges. Ground and surface water control on slopes.
985.1	985.8	**Buck Creek – KP 986.7** East approach slope is gentle, with moderate slopes farther east. No stability problems noted. There is a road partway up the west slope which is terraced with variable slopes that are locally moderate to steep. The stream is meandering with lateral erosion of the meanders evident. There were several oxbows along the valley bottom near and west of the crossing. The valley bottom is wet with muskeg. The wet ground with numerous oxbow ponds extends up to a logging road on the toe of the west valley slope. There is dead standing timber either from a fire (most likely) or from an increase in water elevation. There were a few beaver dams, but no appreciable ponds. The bottom is	Locations of sagbends should consider ongoing lateral erosion of stream. A long crossing over most of the width of the valley bottom may be required. Geotechnical ground reconnaissance recommended. **Open Cut Crossing**: Feasible from a geotechnical point-of-view. Based on predicted flows, isolation using dam and pump or flume, depending on flows, would be possible over most of the year, except May and June.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		cobbles with a few boulders. There was a lot of flaggy rock along the bottom and the bottom of the stream channel may be close to bedrock. The west approach slope is gentle to moderate. <u>Surficial geology</u> (Tipper, 1994): On west edge of higher elevation terrain that may not have been glaciated during last glaciation (Fraser glaciation). Older glacial and glaciofluvial deposits. Buck Creek valley is at the junction of two glaciofluvial outwash valleys to the south. Local observation indicates fine sediments including sand on floodplain. <u>Bedrock geology</u> (Tipper, 1976): Eocene and Oligocene Endako Group: Buck Creek Volcanics (andesite, dacite, minor basalt) to east and some areas of intrusives (granodiorite and quartz monzanite) to west. Major regional fault running to northwest controls local creek valley and channel. Bedrock map indicates thick alluvium (probably glaciofluvial) along Buck Creek.	Ground and surface water control required on slopes. Trench blocks will likely need drains.
985.8	999.85	Lower terrain through tributary valley to Buck Creek at start of segment and then across higher rock controlled ridges to west. <u>Surficial geology</u> (Tipper, 1994) Outwash in glaciofluvial outwash valley tributary to Buck Creek. To west, till (depth not indicated) overlying rock. Local observation suggests several areas of outcrops and probably relatively shallow rock across western half of segment. GEM terrain mapping indicates predominantly till with some areas of veneer and blankets. Local observations indicate several areas of rock outcrops between KP 993 and 998. <u>Bedrock geology</u> (Tipper, 1976) Tiptophill Volcanics (biotite hornblende andesite and andesitic dacite, part of Ootsa Lake Group); Bulkley intrusives (granodiorite and quartz monzanite); Telkwa Formation (variegated red, maroon, grey green breccia, tuff and flows (basalt to rhyolite) near west end of segment.	Bedrock controlled ridges with several areas of outcrop. Local areas of steep slopes along ridges. KP 993.2: Parrott Creek crossing. Meandering creek with gentle to moderate sideslopes. Ground and surface water control required on slopes.
999.85	1002.3	Rolling terrain with typically gentle to moderate slopes. <u>Surficial geology</u> (Tipper, 1994) GEM terrain mapping indicates glaciofluvial sediments along valley. <u>Bedrock geology</u> (Tipper, 1976): Much of area is drift covered, but some outcrops of Telkwa Formation (variegated red, maroon, grey green breccia, tuff and flows (basalt to rhyolite) and undivided volcanics.	Glaciolacustrine sediments have triggered major instabilities farther north. Grading plans involving significant cuts and fills should be reviewed in detail in this area. Ground and surface water control required on slopes including gentle slopes toward the Morice River/Owen Creek area.
1002.3	1002.7	**<u>Owen Creek – KP 1002.5</u>**	Detailed ground reconnaissance work may suggest minor

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Slightly meandering creek slightly misfit on a flat valley bottom with moderately steep approach slopes to east and west. Spawning channels downstream near Morice River. Surficial geology (Tipper, 1994) To west, till (depth not indicated) overlying rock. Local observation suggests areas of rock outcrops across ridges. GEM terrain mapping indicates predominantly glaciolacustrine sediments. Local observation and past experience indicates that there may also be glaciolacustrine sediments in the area. Bedrock geology (Tipper, 1976): Outcrops of Telkwa Formation (variegated red, maroon, grey green breccia, tuff and flows (basalt to rhyolite) and undivided volcanics.	changes in alignment. Approach slopes may require local pull back. Ground and surface water control including trench blocks and likely drains will be required.
1002.7	1007.7	Upland terrain. Gently to moderately sloping terrain, mostly within existing cut blocks. Surficial geology (Tipper, 1994) Till. GEM terrain mapping indicates till blankets, some areas of rock outcrops, local glaciofluvial sediments. Bedrock geology (Tipper, 1976): Outcrops of Telkwa Formation (variegated red, maroon, grey green breccia, tuff and flows (basalt to rhyolite) and undivided volcanics.	Ground and surface water control on areas of slopes.
1007.7	1008.1	**Tributary to Fenton Creek and Fenton Creek KP 1007.5 and KP 1007.9** Steep slopes on both streams. Surficial geology (Tipper, 1994) Till. GEM terrain mapping indicates till or colluvium blankets. Bedrock geology (Tipper, 1976): Sporadic outcrops of undifferentiated volcanics	Ground reconnaissance recommended. Slopes may need to be pulled back to shallower angles. Shoofly around area including existing forestry roads will be required for access. Ground and surface water control including trench blocks and drains.
1008.1	1013.2	Upland terrain. Gently to moderately sloping terrain, mostly within existing cut blocks. Surficial geology (Tipper, 1994) Till. GEM terrain mapping indicates till blankets, some areas of rock outcrops, local glaciofluvial sediments, some areas of shallow muskeg. Bedrock geology (Tipper, 1976): Outcrops of Telkwa Formation (variegated red, maroon, grey green breccia, tuff and flows (basalt to rhyolite) and undivided volcanics.	Ground and surface water control as required. Direct water away from slopes into stream valleys. KP 1010.1 Tributary to Morice River. Slopes will likely need to be pulled back to shallower angles. Ground and surface water control including trench blocks and drains.
1013.2	1014.1	**24.5 Mile Creek KP 1013.5** Crossing of creek and tributary to west. Surficial geology (Tipper, 1994) Till. GEM terrain mapping indicates till blankets, some areas of rock outcrops, and glaciofluvial sediments.	Minor adjustment of route may be required, in particular on east side where route at present appears to sidehill into the creek. Ground reconnaissance recommended. Slopes will likely need to be pulled back. Shoofly around

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		<u>Bedrock geology</u> (Tipper, 1976): Outcrops of Telkwa Formation (variegated red, maroon, grey green breccia, tuff and flows (basalt to rhyolite) and undivided volcanics.	area including existing forestry roads will be required for access. Ground and surface water control including trench blocks and drains.
1014.1	1018.2	Upland terrain. Gently to moderately sloping terrain, mostly within existing cut blocks. <u>Surficial geology</u> (Tipper, 1994) Till. GEM terrain mapping indicates till blankets, some areas of rock outcrops, local glaciofluvial sediments, some areas of shallow muskeg. <u>Bedrock geology</u> (Tipper, 1976): Outcrops of Telkwa Formation (variegated red, maroon, grey green breccia, tuff and flows (basalt to rhyolite) and undivided volcanics.	Ground and surface water control including trench blocks and drains. KP 1017.4 Tributary of Lamprey Creek
1018.2	1019.2	**<u>Lamprey Creek KP 1018.5</u>** Steep slopes into and out of creek. Small slide on east slope. <u>Surficial geology</u> (Tipper, 1994) Till. GEM terrain mapping indicates glaciofluvial sediments and till. Local observations suggest that glaciolacustrine sediments may also be present. <u>Bedrock geology</u> (Tipper, 1976): Outcrops of Telkwa Formation (variegated red, maroon, grey green breccia, tuff and flows (basalt to rhyolite) and undivided volcanics.	Ground reconnaissance of area recommended. Small adjustments of route may be required to miss slide. Slopes will likely need to be pulled back. Shoofly around area including existing forestry roads will be required for access. Ground and surface water control including trench blocks and drains.
1019.2	1024.5	On sidehill just above terrace bordering Morice River. Route follows a bench for much the length of the segment. <u>Surficial geology</u> (Tipper, 1994) Till. GEM terrain mapping indicates till and some fluvial sediments. Based on local observation, the presence of glaciolacustrine sediments cannot be excluded. <u>Bedrock geology</u> (Tipper, 1976): Micaceous greywacke, shale, minor conglomerate and shale).	Crossings of streams tributary to Morice River. Detailed consideration of cut design required. Keep all cuts and fills as low as possible, use narrow than standard grade if required to do this. Do not divert surface water down RoW. Ground and surface water control required.
1024.5	1030.6	Higher terrain including sidehill terrain and benches south of Morice River. <u>Surficial geology</u> (Tipper, 1994) Till, some areas of shallow rock. GEM terrain mapping indicates similar. <u>Bedrock geology</u> (Tipper, 1976): Micaceous greywacke, shale, minor conglomerate and shale.	KP 1025.8 Cedric Creek Ground and surface water control required.
1030.6	1037.4	On sidehill paralleling south side of existing logging road. Tight area on sidehill. Frequent rock exposures along road cut.	Detailed consideration of cut design recommended. Keep all cuts and fills as low as possible, use narrow than

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Route on south side of road is preferred due to slides at some locations (KP 1034.8 to KP 1035.8) and steep sideslopes. Surficial geology (Tipper, 1994) Till. GEM terrain mapping indicates till blankets and steep rock. Bedrock geology (Tipper, 1976): Telkwa Formation (variegated red, maroon, grey green breccia, tuff and flows (basalt to rhyolite) and undivided volcanics and undifferentiated volcanics.	standard grade if required to do this. Do not divert surface water down RoW. Ground and surface water control required.
1037.4	1038.6	**Route turns and runs down slope toward Morice River** **Morice River KP 1038.0** Moderate slope on south side of river has variable slopes and a terrace near the toe. Areas of rock outcrop high on the slope but no outcrop found lower on slope. River is relatively stable and does not appear subject to appreciable lateral erosion. Route is parallel to existing logging road bridge. Surficial geology (Tipper, 1994) Glaciofluvial deposits. GEM terrain mapping indicates extensive glaciofluvial deposits near river and on north side of river with till blankets partway up the slope. Bedrock geology (Tipper, 1976): Telkwa Formation (variegated red, maroon, grey green breccia, tuff and flows (basalt to rhyolite) and undivided volcanics. Some northeast to northwest oriented faults in area.	**Directionally Drilled Crossing**: Geometrically feasible, but detailed geology conditions not known. There is a possibility of coarse glaciofluvial sediments that could be a problem for a directionally drilled crossing depending on depth. Further investigations required. **Trenched Crossing**: Feasible from a geotechnical point-of-view. Flows are too high for isolation at all times of year. Ground and surface water control required on south side of river.
1038.6	1058.6	Route runs along undulating bench on the south side of the Gosnell Creek valley. At end of segment, route runs out across south valley floor of Gosnell Creek. Gentle slopes. Parallel or near logging roads. Surficial geology (Tipper, 1994): Extensive glaciofluvial outwash at east end of segment. To the west, the valley was a glaciofluvial outwash channel and there are likely glaciofluvial deposits along the valley as suggested by the aerial reconnaissance. Based on the aerial reconnaissance, the deposits along the bench may be a mixture glacial till and glaciofluvial outwash. The proposed route on the south side of the valley would miss most of the areas of muskeg along the valley floor. GEM terrain mapping indicated mostly till except extensive glaciofluvial deposits near Tributary to Gosnell Creek (KP 1044) and to the west. West of KP 1046 (approx.) route is on toe of till covered south valley slope of Gosnell Creek valley. Extensive glaciofluvial deposits along valley bottom. KP 1057 – route bends away from main valley slope across valley bottom toward Gosnell Creek crossing.	Numerous small tributaries to Gosnell Creek in addition to those noted. KP 1044.4 Crystal Creek (tributary to Gosnell Creek). Possible small alluvial fan. Route may need adjustment of route within corridor due to lateral erosion of stream and meander bend to north. Crossing design will need to consider lateral and possibly downcutting erosion. KP 1057.0 Tributary stream to Gosnell River valley has alluvial fan and may be subject to avulsion. Crossing design will need to consider lateral and possibly downcutting erosion. Ground and surface water control required on slopes.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Bedrock geology (Tipper, 1976): Telkwa Formation (part of Hazelton Group) variegated red, maroon, grey breccia, tuff and flows.	
1058.6	1059.1	**Gosnell Creek. – KP 1058.9** Gravel bottom meandering stream. Areas of muskeg and generally high groundwater table across valley bottom. Surficial geology (Tipper, 1994): Glaciofluvial deposits along the valley as suggested by aerial reconnaissance. Areas of muskeg. Bedrock geology (Tipper, 1976): Telkwa Formation (part of Hazelton Group) variegated red, maroon, grey breccia, tuff and flows.	**Open Cut Crossing**: Appears to be feasible from a geotechnical point-of-view. Suitable allowance for lateral erosion would be required. Based on flows, isolation possible December through April using flumes.
1059.1	1066.1	Ridged terrain through pass at headwaters of Gosnell Creek and a tributary of the Burnie River to the west. Existing logging roads end beyond Gosnell Creek crossing. The route generally runs along the toes of slopes on the north side past an unnamed lake in the pass south of the route. At west end, route runs south of another small lake. . Surficial geology (Tipper, 1994): Tipper indicates main glaciofluvial channel was along the alignment of the lakes south of the proposed route. Based on aerial reconnaissance, the deposits along the proposed route likely consist of glacial till, glaciofluvial sediments, local alluvium, and colluvium overlying shallow rock with rock exposures. There are areas of muskeg. GEM terrain mapping indicated Bedrock geology (Tipper, 1976): Telkwa Formation (part of Hazelton Group) variegated red, maroon, grey breccia, tuff and flows on west side.	KP 1060.6: Tributary to Gosnell Creek **Difficult area:** KP 1060.3 to KP 1065.8: Gentle to moderate sideslope with steep segments. Rock ridges, frequent small streams, rough cross slope topography. Ground reconnaissance and detailed consideration of grading design. Cross berms and trench blocks will be required to some extent depending on final grading design. Cuts through ridges of Telkwa Formation may have poorer stability and require flatter angles than other typical rock formations encountered elsewhere on the route, depending on local rock properties. Toward the end of the segment, the route runs down the moderate to locally steep slopes forming the south approach slope to the Burnie Creek valley. There are stability concerns to the west along the side of this ridge that were seen from the air (route was adjusted to miss these areas). Adjustment of the route relative to a small tributary stream channel may also be required. Further ground geotechnical reconnaissance of the route on the side of the ridge is recommended. Ground and surface water control. Trench blocks will be required at some locations. Detailed consideration of cuts on sideslopes, particularly near streams.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
1066.1	1067.3	Tributary to Burnie River in pass area. Surficial geology: Observations from air indicated alluvial fan that may be subject to avulsion. May have alluvial fan subject to avulsion. Also may be subject to debris torrents, although it appears that the main deposition area may be upstream of crossing.	**Alluvial fan** KP 1066.0 to KP 1067.0: Alluvial fan with old channels. Possible avulsion should be further reviewed on LiDAR when available and in field. Possible debris flows, although main area of deposition appeared to be upstream of pipeline route. Location of crossing, depth of cover and length of crossing relative to possible avulsion and erosion should be reviewed during detailed design.
1067.3	1069.4	Route runs south of a small lake. . Surficial geology (Tipper, 1994): Tipper indicates main glaciofluvial channel was along the alignment of the lakes south of the proposed route. Based on aerial reconnaissance, the deposits along the proposed route likely consist of glacial till, glaciofluvial sediments, local alluvium, and colluvium overlying shallow rock with rock exposures. There are areas of muskeg. GEM terrain mapping indicated Bedrock geology (Tipper, 1976): Telkwa Formation (part of Hazelton Group) variegated red, maroon, grey breccia, tuff and flows on west side.	Ground and surface water control on slopes.
1069.4	1071.1	Route runs parallel to but below crest of large ridge. Near end of segment, bends and runs directly downslope on ridge. Local observation indicates shallow glacial till on upper part of ridge with glaciofluvial and sediments on lower part of ridge. Bedrock geology (Tipper, 1976): Telkwa Formation (part of Hazelton Group) variegated red, maroon, grey breccia, tuff and flows on west side. May be intrusives on parts of ridge.	Shallow bedrock with some areas of rock cut. KP 1070.3 to KP 1071.1 (approx.) Shoofly required in area for approach to east end of Clore tunnel. KP 1070.8 (approx.) Possible shallow slide in colluvium or till to north of route.
1071.1	1071.4	**Tributary to Burnie River – KP 1071.2** Stream is incised into glaciofluvial and possibly glaciolacustrine sediments with two areas of lower slopes. Slightly meandering stream. Surficial geology: Local mapping indicates remnant glaciofluvial terraces and possibly glaciolacustrine deposits. Much of these deposits have been removed by the downcutting of the Clore since the end of glaciation (see below). Bedrock geology (Read 2006): Red Rose Formation: Micaceous greywacke, grey to black shale; some conglomerate and coal. Coast Range Plutonics on south side of valley.	**Open Cut Crossing**: Appears to be feasible from a geotechnical point-of-view. Isolation appears possible based on flows but superflume would be required over the summer months.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
1071.4	1072.3	Route runs across Clore valley. Surficial geology As above. Local deposits of glaciofluvial and alluvial sediments, muskeg. Generally shallow bedrock. Work by Read (2006) and local observations indicate that stream piracy and erosion of the Clore River Canyon has resulted in lowered base levels and erosion of much of the formerly existing valley fill, exposing bedrock along parts of the river valley bottoms and/or reducing the cover. Bedrock geology (Read 2006): Red Rose Formation: Micaceous greywacke, grey to black shale; some conglomerate and coal. Coast Range plutonic rock on south side of valley.	Ridged to knobby terrain with frequent areas of weak bedrock.
1072.3	1072.8	**Clore River – KP 1072.5** Crossing of Clore River. Narrow terrace on south side with river incised up to approximately 30 m depending on location. Variable but locally steep slope on east side of crossing. Some areas of shallow sliding where undercut by river. Relatively wide alluvial braided channel. River discharges from a rock canyon approximately 500 m upstream of Rev R centerline and is tending to fan out and erode laterally. Fluvial gravel deposits subject to erosion over a width of about 150 m. West side has two low terraces, the lowest terrace is being eroded laterally by river. River appears to be eroding laterally on both sides and the extent of active lateral erosion will likely increase in the future. Surficial geology: Work by Read (2006) indicates that a lowering of base level due to post-glacial erosion of the Clore River canyon has resulted in erosion and removal of most of the glacial and glaciofluvial deposits along what is now the Clore valley upstream of the canyon. Shallow or bare rock with sometimes deeply incised streams. Some valleys in bedrock infilled with sediments. Bedrock geology (Read 2006): Red Rose Formation: Micaceous greywacke, grey to black shale; some conglomerate and coal. Pyrite seen in formation by P. Read during preliminary field work.	Crossing design should consider lateral erosion which may extend both to the east and west in future. The final design and possibly location of the crossing will need to consider the location and design of the east portal of the Clore Tunnel. Further consideration during detailed design may be required. **Open Cut Crossing:** Feasible, but relatively long (perhaps 200 m or more). Both lateral and scour erosion would need to be considered in design. Isolation only possible January to March and would be marginal for flume (superflume likely required). Seepage through gravel substrates may be an issue. **Directional drilling**: Appears to be geometrically not feasible on the Rev R alignment.
1072.8	1079.2	**Clore Tunnel** Tunnel under ridge west of Clore Canyon. See AMEC (2009a).	
1079.2	1080.4	**Tributary to Clore River – KP 1079.8**	**Aerial Crossing**: Preferred method from geotechnical

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Crossing at Rev. P (close to preferred route in this area) would be at a deep canyon with near vertical walls (depth uncertain but approx. 50 m). Shoofly crossing is available a short distance to south. Surficial geology: GEM Terrain Mapping - Colluvial and till deposits, mostly thin on top of bench. Steep rock slopes. Bedrock geology Read (2006): Middle Member Telkwa Formation: varigated breccia, tuff and flows.	point-of-view. Additional geotechnical engineering to examine foundation conditions at crossing will be required.
1080.4	1086.9	**Hoult Tunnel** Tunnel under Nimbus Mountain. See AMEC (2009a).	
1086.9	1087.2	**Hoult Creek – KP 1086.9** Crossing would be located upstream of waterfall where the creek is small and shallow with low banks at the head of a canyon that deepens downstream. Surficial geology: Scree slopes and shallow rock. Till veneers and colluvium at lower elevations. Extensive alluvial deposits along creek channels. Bedrock geology Read (2006): Granite, granodiorite and related intrusives of various ages.	Crossing close to an area of avalanches and rockfall but crossing and route appear to be clear of problem area. **Aerial Crossing**: Additional geotechnical engineering to examine foundation conditions at crossing will be required.
1087.2	1089.75	Through cut blocks on north side of Hoult Creek. Moderate sideslopes with locally steeper areas of sideslope. Surficial geology: Glacial till and possible glaciofluvial sediments with areas of exposed or shallow bedrock. Bedrock geology: Read (2006): Bulkley Intrusions(?) (Post-tectonic quartz diorite, diorite, granodiorite; more hornblende than biotite; fresh, altered; unfoliated to weakly foliated). Middle Member Telkwa Formation: varigated breccia, tuff and flows.	KP 1088.0: Stream crossing at approximately KP 1088.0 may be considered slightly higher on slope from a geotechnical point-of-view. Stream may be subject to debris flows. **Difficult cross slopes** Start of area where detailed geotechnical, hydrotechnical and civil engineering planning using cross sections is recommended during detailed design. Variable but locally steep cross slopes with incised creeks, some of which are subject to debris flows.
1089.75	1098.4	Steep sideslopes along road above Hoult Creek and Kitimat River. Surficial geology: Elevations above approximately 225 m which is expected to be above elevation of marine transgression. Glacial till veneers to blankets, colluvium and glaciofluvial sediments. Some of these materials are on sloping rock surfaces. Areas of seepage. Bedrock geology (Woodsworth, Hill and van der Heyden, 1985): Telkwa	**Difficult cross slopes** Detailed geotechnical, hydrotechnical and civil engineering planning using cross sections is recommended during detailed design. General approach would be to widen existing rock cut and

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Formation (basalt to rhyolite breccia, tuff and flows, minor sediments). Read (2006): Bulkley Intrusions(?) (Post-tectonic quartz diorite, diorite, granodiorite; more hornblende than biotite; fresh, altered; unfoliated to weakly foliated). Middle Member Telkwa Formation: varigated breccia, tuff and flows.	work on a grade as narrow as possible in areas of steep rock cross slope. Local avalanche conditions during winter in parts of upper part of Kitimat valley may be a consideration during construction and should be considered with respect to design of a few of the creek crossings. Streams at KP 1089.75, KP 1090.6, KP 1091.15, KP 1092.6, and KP 1094.2 may be subject to debris flows. Most also have colluvial or alluvial fans where avulsion may be a consideration. Rockfall may be a consideration from steep slopes and/or down some steep stream valleys.
1098.4	1099.2	**<u>Hunter Creek – KP 1098.8</u>** Rev. P route is on sidehill and close to or in creek to north. Depending on final crossing method, local route adjustments may be required. The existing logging road bridge is located upstream of a bridge that washed out a few years ago. During this washout, Hunter Creek relocated to a channel that is close to the toe of the north slope of the valley. Other older channels exist at various locations on the Hunter Creek fan and channel avulsion (switching) has occurred frequently in the past. Debris flows, movements of large amounts of bouldery bed materials and debris flows will be geotechnical/hydrotechnical design considerations in this area. <u>Surficial geology</u>: Scree slopes and shallow rock. Till veneers and colluvium at lower elevations. Extensive alluvial deposits along creek channels. Hunter Creek valley has extensive terraced deposits of glaciofluvial alluvium with some till along the channel and on the adjacent valley slopes of the Kitimat River. Glaciofluvial fan or kame fan deposits on Kitimat River valley to west of bridge crossing of creek. Channel is meandering above the bridge and is located on an alluvial fan at and below the road bridge. <u>Bedrock geology</u> (Woodsworth, Hill and van der Heyden, 1985): Telkwa Formation (basalt to rhyolite breccia, tuff and flows, minor sediments). Read (2006): Middle Member Telkwa Formation: varigated breccia, tuff	**Directionally Drilled Crossing**: A directionally drilled crossing may be feasible based on preliminary information. **Open Cut Crossing**: Would be feasible from the geotechnical and hydrotechnical points-of-view, but would need to consider avulsion and scour erosion. Crossing would be relatively long in course bouldery alluvium. Based on flows, diversion would be possible in winter, however, high flows through permeable bed materials and steep gradients would likely make diversion not practical.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		and flows.	
1099.2	1103.9	Route is generally located on the uphill side of the existing road. Areas of steep sideslope toward the end of the segment with two tributary stream crossings in segment. KP 1101.9: Stream channel has exposed bedrock in bottom of channel. KP 1102.3**:** Stream channel has been subject to debris flows and erosion along the channel possibly caused by diversion of water along an old logging road higher up the slope. Frequent groundwater seepage and areas of groundwater piping. <u>Surficial geology</u>: Elevations above approximately 225 m which is expected to be above elevation of marine transgression. Glacial till veneers to blankets, colluvium and glaciofluvial sediments. Some of these materials are on sloping rock surfaces. Areas of seepage. <u>Bedrock geology</u> (Woodsworth, Hill and van der Heyden, 1985): Telkwa Formation (basalt to rhyolite breccia, tuff and flows, minor sediments). Read (2006): Also indicates Middle Member Telkwa Formation.	**Difficult area.** Groundwater piping control including drains and rock blankets will be required. Filter berms may be required in some areas during and following construction to control the transport of sediment along the RoW, including sediment generated upslope of the RoW. Detailed geotechnical, hydrotechnical and civil engineering planning using cross sections is recommended during detailed design. KP 1101.9 and KP 1102.4: Streams may be subject to debris flows. Streams may have alluvial or colluvial fans. Possible avulsion. **Reroute**: Route should be uphill of logging road. Further engineering will be required to finalize route through area.
1103.9	1112.9	North side of Kitimat River along toe of north valley slope. Preferred route is located on uphill side of existing logging road, subject to further geotechnical investigation. Concave up slopes, moderate to locally steep in lower part of valley near route becoming steep farther upslope. Several stream crossings. <u>Surficial geology</u>: Elevations above approximately 225 m which is expected to be above elevation of marine transgression. Glacial till veneers to blankets, colluvium and glaciofluvial sediments. Kame glaciofluvial fan sediments on sideslopes near creek crossings. Some of these materials are on sloping rock surfaces. Areas of seepage. <u>Bedrock geology</u> (Woodsworth, Hill and van der Heyden, 1985): Telkwa Formation (basalt to rhyolite breccia, tuff and flows, minor sediments). Read (2006, mapping along edge of road): Middle Member Telkwa Formation: varigated breccia, tuff and flows east of KP 1105.4. West of KP 1105.4: Post-tectonic quartz diorite, diorite, granodiorite; more hornblende than biotite; fresh, altered; unfoliated to weakly foliated.	**Difficult area.** The preferred route is generally expected to be in close proximity to the road; however, more detailed work should be done to check the possibility of routes slightly above the road on terrain benches. Near KP 1108.4: Areas of shallow sliding and debris flows of overburden materials on sloping rock and within overburden materials aided by groundwater seepage. Shotrock blankets over non-woven geotextile will be required to allow seepage to exit the cut slopes without piping the underlying soil. Debris traps and filter berms should be considered at suitable locations to trap sediment eroded onto the pipeline RoW from higher up slope in order to reduce the general transport of sediment from areas off RoW toward spawning channels in the Kitimat River system. Some degree of ongoing maintenance is expected in these areas due to the transport of off RoW sediment across the RoW during operation. Suitable measures should generally improve the local sedimentation situation.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
			KP 1105.2, KP 1108.2, KP 1108.8, KP 1109.4, KP 1109.6, KP 1111.1, KP 1112.6: Streams may be subject to debris flows. Streams may have alluvial or colluvial fans. Possible avulsion. Detailed geotechnical, hydrotechnical and civil engineering planning using cross sections is recommended during detailed design.
1112.9	1119.9	Lower Kitimat River Valley. Preferred route is located close to the existing logging roads, but on uphill side. Slopes along lower valley slopes are moderate to gentle with benches and terraces. Surficial geology (Clague, 1984): Elevations slightly below approximately 215 m which is below the approximate elevation of marine transgression where there may be glaciomarine clays; however, no evidence of any glaciomarine clay-related stability issues identified to date. Glacial till veneers to blankets, colluvium and glaciofluvial sediments. Some of these materials are on sloping rock surfaces. Rock knobs. Areas of seepage. Bedrock geology: East part of segment (Woodsworth, Hill and van der Heyden, 1985): Telkwa Formation (basalt to rhyolite breccia, tuff and flows, minor sediments). Toward west: granodiorite and greenschist facies diorite (low grade metamorphosed diorite). Read (2006, mapping along edge of road): Post-tectonic quartz diorite, diorite, granodiorite; more hornblende than biotite; fresh, altered; unfoliated to weakly foliated.	**Difficult area.** While area is in the upper part of the elevation zone in which marine clay could occur, no marine clay related instability has been identified to date and sensitive clay may not be present in this area. Further checks including drilling to check the properties of soils at depth are recommended. Ground and surface water control required. Rock blankets may be required if groundwater seepage is encountered in cuts. Preferred route is generally on uphill of logging road. Further engineering will be required to finalize route through area. KP 1115.9: The Kitimat River is eroding laterally toward the logging road aided by groundwater piping of the sediments in the river bank. The road may eventually be eroded by this lateral migration (route is located above road). KP 1113.9, KP 1114.9, KP 1116.0, KP 1116.6: Streams may be subject to debris flows. Streams may have alluvial or colluvial fans. Possible avulsion.
1119.9	1122.8	Along the north side of Chist Creek which flows back along the north side of the Kitimat valley. Surficial geology (Clague, 1984): Elevations below approximately 225 m which is below the approximate elevation of marine transgression where there may be glaciomarine clays. An occurrence	**Difficult area.** While area is in the upper part of the elevation zone in which marine clay could occur, no marine clay related instability has been identified to date. Further checks including drilling to check the properties of soils at depth

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		of marine clay has been reported by Seiler (2006) in the bottom of the Chist Creek channel west of KP 1120.9. Silty fine sand deposits were noted in river bank near start of segment. Glacial till veneers to blankets, colluvium and glaciofluvial sediments. Areas of seepage including groundwater piping. At start of segment, Chist Creek is eroding toward the south into a high slope of sand and gravel. Bedrock geology: East part of segment (Woodsworth, Hill and van der Heyden, 1985): Telkwa Formation (basalt to rhyolite breccia, tuff and flows, minor sediments). West part of segment: granodiorite and greenschist facies diorite (low grade metamorphosed diorite). Read (2006, mapping along edge of road): East part of segment: Post-tectonic quartz diorite, diorite, granodiorite; more hornblende than biotite; fresh, altered; unfoliated to weakly foliated. Near crossing of Chist Creek - Greenschist facies diorite-tonalite complexes; lesser metavolcanic rocks; unfoliated to weakly foliated; intense brittle deformation.	are recommended. Ground and surface water control required. Rock blankets may be required if groundwater seepage is encountered in cuts. KP 1122.3: Stream may be subject to debris flows. Stream may have alluvial or colluvial fan. Possible avulsion.
1122.8	1123.5	**Chist Creek – KP 1123.1** Existing road bridge crossing is on a rock ridge which is a buried extension of the adjacent rock slopes on the north side of the Chist Creek valley. This rock ridge is expected to be of limited extent. Chist Creek is eroding toward the south and west downstream of the bridge. Upstream of the bridge, the creek is eroding to the south toward the road. Bottom sediments in the creek are reported by Seiler (2006) to be highly mobile. Surficial geology (Clague, 1984): Alluvial terrace and floodplain deposits near creek. Exposed deposits are bouldery. Onion Creek glaciofluvial delta a short distance to west with exposures of sand and gravel along creek channel. There may be glaciomarine clays at depth. Bedrock geology (Woodsworth, Hill and van der Heyden, 1985): Adjacent to granodiorite and greenschist facies diorite, tonalite (low grade metamorphosed diorite). Read (2006, mapping along edge of road): Greenschist facies diorite-tonalite complexes; lesser metavolcanic rocks; unfoliated to weakly foliated; intense brittle deformation.	**Open Cut Crossing**: Feasible from a geotechnical point-of-view. The possibility of lateral erosion at the crossing would need to be further considered. Note that the stream has migrated laterally to the east several tens to well over 100 m farther downstream. Preferred location would be close to the existing road bridge, possibly with riprap (if required) along the outside bend upstream of the bridge to control local lateral erosion in this area. Based on flows, isolation using flume or superflume would be possible from December through March or possibly April. Flows through permeable sandy substrates may be a consideration both with respect to flow volume and also trench stability.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
1123.5	1131.1	Route runs to the west across terrain that is close to level on the Onion Creek delta. Surficial geology (Clague, 1984): Onion Creek fan. Mapped as kame and ice stagnation deposits. Hummocky to rolling, may contain inclusions of diamictons. Glaciomarine clay sediments are exposed over 1 km south of the route and have been subject to several past flow failures.	The route in this area has been established well back from the areas in which past glaciomarine clay failures have occurred. Further checking of route and underlying materials and stability is recommended.
1131.1	1132.2	**Cecil Creek – KP 1131.4** Ground reconnaissance of the north side of the creek indicated terraced deposits of sand and gravel. No indication of slide movements has been identified in this area. Surficial geology (Clague, 1984): Undifferentiated terrace scarps and river banks. Creek slopes eroded into Onion Creek glaciofluvial fan as above.	**Open Cut Crossing**: Feasible from a geotechnical point-of-view at existing crossing. Substantial amounts of grading on approach slopes. Ground and surface water control would be required. Isolation would be possible at most times of year.
1132.2	1137.1	West of Cecil Creek and north of Iron Mountain. Route diverts to west around area of erosion and shallow sliding, apparently related to glaciomarine sediments. Surficial geology (Clague, 1984): Onion Creek delta. Mapped as kame and ice stagnation deposits. Hummocky to rolling, may contain inclusions of diamictons. Near the south end of segment, mapped as shallow till over rock or exposed rock. Some areas of organics (muskeg).	KP 1133.5 to KP 1137.3: Route follows toe of Iron Mountain to avoid erosion and sliding to east. KP 1136.8 (approx): Waterfall with potential local rockfall.
1137.1	1140.5	East side of Iron Mountain. Helicopter reconnaissance suggests area is underlain by a mixture of glaciofluvial sand and possibly glaciomarine clay with rock ridges. Some areas of shallow ponding and muskeg. Surficial geology (Clague, 1984): Rolling glaciomarine clays, gullied. Hole R02 drilled near Deception Creek did not encounter sensitive glaciomarine clay (the clay encountered was stiff to hard).	No stability issues identified during helicopter reconnaissance. Potential slope stability problems in glaciomarine clay. Further geotechnical review recommended. If concerns are identified in this area, a route farther west along the edge of Iron Mountain could potentially be considered. Several wet areas that may be soft due to underlying glaciomarine clay. Local routing should attempt to avoid these areas as much as possible. Some linear areas will not be possible to avoid. KP 1140.0 Deception Creek: Area is wet on north side of crossing. Consider diverting a short distance to the east to

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
			improve conditions. A hole drilled by AMEC at about KP 1140.0 on the east side of Iron Mountain near Deception Creek (R02) did not encounter sensitive glaciomarine clay, although stiff to hard high plastic clay was encountered below sand deposits from 44 m to the bottom of the hole at 66.5 m. ARD considerations are discussed in AMEC (2009c and 2009d).
1140.5	1144.1	On east lower slopes of Iron "Mountain". Surficial geology (Clague, 1984): Exposed rock and till veneers over rock. Bedrock geology (Woodsworth, Hill and van der Heyden, 1985) greenschist facies diorite, tonalite.	Rock grading. Check local rock stability conditions. Local lore is that Iron Mountain is named after a magnetic anomaly. ARD considerations are discussed in AMEC (2009c and 2009d). At south end of segment, route transitions from the east and southeast sides of Iron Mountain to the Wedeene River valley. The stability conditions in this transition area will need further field investigation possibly including drilling to check for sensitive clay.
1144.1	1145.0	**Wedeene River KP 1144.5** Railway crosses river on a bridge founded on rock upstream of proposed pipeline crossing. Along the river there are prominent rock ridges in the valley and areas of rock outcrop close to river elevation for approximately 650 m southeast. These ridges appear to line up with areas of possible shallow rock and/or rock outcrops in the upland areas. Between the ridges on the south side of the river, Lidar hillshade maps, airphoto interpretation and field observations suggest that there may be marine clay slides between the ridges south of the river. Surficial geology (Clague, 1984): Till veneers on north side. Alluvial terraces on south side (sand and gravel). Downstream (east) of crossing: alluvial sediments overlying glaciomarine clay. Bedrock geology (Woodsworth, Hill and van der Heyden, 1985) greenschist facies diorite, tonalite. May be Telkwa Formation (basalt to rhyolite breccia, tuff and flows, minor sediments).	**Very Difficult Area** Further geotechnical investigations will be required to delineate the surficial geology, bedrock topography and stability conditions. Issues include potential stability issues, river crossing and rail crossing, all in close proximity to each other. **Directionally Drilled Crossing**: Feasibility of directional drilling will depend on the surficial geology conditions including depth and boulder content of the sediments and possibly on the depth and presence of glaciomarine deposits. Marine clay stability may be an issue. A successful directionally drilled crossing could potentially cross the river, areas of potential stability issues and the railway. Further work would be required to determine feasibility. **Open Cut Crossing**: A conventional crossing in the rock

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
			channel could be considered but may be difficult due to presence of railway directly to the south. Blasting of in-water bedrock would be required which may also be difficult. From a geotechnical point-of-view, a conventional crossing is considered less preferable. **Other Trenchless Methods**: Other trenchless methods appear to be feasible from a geotechnical point of view subject to further investigation.
1145.0	1148.2	Rolling terrain with some terrace elevation changes. <u>Surficial geology</u> (Clague, 1984): Glaciofluvial delta sand and gravel at north and south ends of segment. Glaciofluvial veneer overlying glaciomarine clays in center third of segment.	Geotechnical review of route, underlying materials and stability is recommended. KP 1146.7 to KP 1147.1: Wet areas along channels of tributary creeks to Wedeene River.
1148.2	1149.3	**<u>Little Wedeene River – KP 1148.6</u>** Route crosses river approximately parallel to existing forestry road. There is a high eroding sand and gravel slope to the east off the alignment. Gentle and low terraced slopes at proposed alignment. On the south side, wide low terrace with near surface groundwater and muskeg. The river may erode to the south in the future or reoccupy an old channel to the south. <u>Surficial geology</u> (Clague, 1984): Glaciofluvial delta sand and gravel on north side. Alluvial delta sediments (sand and gravel) on south side overlain by variable depths of muskeg. No marine clay seen; however, silty fine grained sand occurs along the river channel on the north side. Drill hole R04 west of KP 1149.8 encountered 15 m of gravel overlying clay, of which a thin layer was sensitive. <u>Bedrock geology</u> (Woodsworth, Hill and van der Heyden, 1985): Adjacent bedrock exposures to the west are Telkwa Formation (basalt to rhyolite breccia, tuff and flows, minor sediments).	**Open Cut Crossing**: Appears feasible from a geotechnical point-of-view. Further consideration of trench stability and access conditions in the muskeg area south of the present channel would be required. Crossing would likely be relatively long to allow for potential lateral erosion or channel reoccupation to the south. Isolation would be marginal using a superflume in winter. Flows would be too high at other times of the year for isolation. **Slope stability**: Review recommended of local slope stability relative to the possible occurrence of glaciomarine clay.
1149.3	1158.6	Mostly flat terraced or benched terrain in Kitimat valley. <u>Surficial geology</u> (Clague, 1984): Northern third of sediment: alluvial sediments, may be on edge of glaciomarine clay to west. Center part of segment, colluvial veneer along toe of rock slope, possible till. Southern third of segment – alluvial sediments. BH 75-3 located 0.7 m to west in thicker part of glaciomarine sediments encountered 42 m of clay, some sensitive. Southern third of sediment – alluvial sediments. Drill holes or water wells by others do not appear to have intersected clay.	Further investigation of local surficial geology conditions recommended relative to possible occurrences of sensitive glaciomarine sediments.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		Bedrock geology (Woodsworth, Hill and van der Heyden, 1985): Telkwa Formation (basalt to rhyolite breccia, tuff and flows, minor sediments).	
1158.6	1160.7	Route runs around east side of a high sand and gravel ridge proposed to be mined. Along edge of steep slopes to west and flat topography underlain by glaciofluvial sediments (possible glaciomarine clay) to east. Drill holes or water wells by others may have intersected clay. Surficial geology (Clague, 1984): Alluvial and glaciofluvial terrace, delta and alluvial fan sediments. May overlie glaciomarine clay, but not shown on available mapping. Some areas of fill. Local contacts indicate that at east edge of gravel ridge, sand and gravel may occur to depth adjacent to the river. Bedrock geology (Woodsworth, Hill and van der Heyden, 1985): Telkwa Formation (basalt to rhyolite breccia, tuff and flows, minor sediments).	**Possibly Difficult Area** Route diverts to east around east end of gravel ridge to be mined for export. This is may also be a congested area with existing railway, pipelines, road, mining facilities and other pipelines and conveyor facilities planned or proposed. Further geotechnical review of static and seismic stability conditions in this area relative to marine clay which may occur near the south end of the segment is recommended. Further review of lateral erosion conditions of adjacent Kitimat River is recommended.
1160.7	1163.7	On west side of Kitimat valley and west valley slopes. Surficial geology (Clague, 1984): Alluvial and glaciofluvial terrace, delta and alluvial fan sediments. May overlie glaciomarine clay, but not shown on available mapping. Some areas of fill. Bedrock geology (Woodsworth, Hill and van der Heyden, 1985): Telkwa Formation (basalt to rhyolite breccia, tuff and flows, minor sediments).	Local route adjustments to optimise conditions may be required. Sidehill slope stability conditions should be further examined, particularly with respect to the possible presence of marine clay.
1163.7	1164.1	**Anderson Creek – KP 1163.8** Crossing is located on a braided alluvial channel at the toe of the rock slope on the west side of the valley. Preferred crossing is upstream of present mill water intake and downstream from an older intake. Surficial geology: Glaciofluvial and alluvial sand and gravel overlying either rock or possibly glaciomarine clay. Close to and east of road, terrain may be underlain by glaciomarine clay, possibly overlain by hydraulic fill. Bedrock geology (Woodsworth, Hill and van der Heyden, undated): Telkwa Formation (basalt to rhyolite breccia, tuff and flows, minor sediments). Note low competency of this formation.	**Slope stability**: Depending on whether the site is underlain by marine clay, there could be lateral spreading considerations or possibly settlement considerations. **Open Cut Crossing**: Feasible from a geotechnical point-of-view at Rev. P route location immediately upstream of road bridge subject to stability and marine clay issues. Isolation may be feasible most of year except summer. Permeable alluvium could be an issue. Note nearby water intake.
1164.1	1165.0	Sidehill along west side of Kitimat valley. Glaciomarine clay on slopes may be sliding or moving in some areas. Movements may be shallow. Evidence of sliding includes pistol butted trees, slide blocks and slide scarps. Movement may be due to sliding or may be due to settlement of adjacent areas of floodplain under	**Slope and seismic stability**: Evidence of movement on slope areas. Route will need to be finalized relative to local stability conditions. Excavation through shallow sliding areas may be required.

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
		hydraulic fill loading. Surficial geology: Glaciofluvial and alluvial sand and gravel overlying either rock or possibly glaciomarine clay. Close to and east of road, terrain is underlain by glaciomarine clay, possibly overlain by hydraulic fill. Bedrock geology (Woodsworth, Hill and van der Heyden, 1985): Telkwa Formation (basalt to rhyolite breccia, tuff and flows, minor sediments). Note low competency of this formation.	
1165.0	1165.3	**Moore Creek- KP 1165.1** Route crosses incised ravine of Moore Creek. Upland area upstream of water fall: 30 to 50 m deep ravine eroded in bedrock. May be subject to debris torrents. Rockfall from canyon walls. Surficial geology: Glaciofluvial and alluvial sand and gravel overlying either rock or possibly glaciomarine clay. Close to and east of road, terrain is underlain by glaciomarine clay, possibly overlain by hydraulic fill. Bedrock geology (Woodsworth, Hill and van der Heyden, undated): Telkwa Formation (basalt to rhyolite breccia, tuff and flows, minor sediments). Note low competency of this formation.	Local adjustment of route to optimise crossing location of the Moore Creek ravine. Further ground reconnaissance recommended. **Aerial Crossing**: Feasible from a geotechnical point-of-view. Would likely provide sufficient clearance from any debris flows or rockfalls. **Trenched Crossing**: Not recommended due to ravine.
1165.3	1170.3	Steep cross slope above marina area at the north end of Kitimat Arm at start of segment with sloping bench to south. Shallow bedrock with till or possibly marine clay. Some large boulders. Areas of steep cross slope. Surficial geology: No detailed mapping has been found. Based on aerial observations, glacial till veneers, possible glaciomarine clay overlying shallow bedrock. Some areas of colluvium and colluvial boulders. Bedrock geology: Detailed mapping has not been found. Projecting from Woodsworth, Hill and van der Heyden (1985) greenschist facies diorite, tonalite.	**Difficult Area, possible slope stability considerations** Further investigation and potentially a route revision during detailed routing is recommended in this area to optimize the route. Detailed consideration of design using cross sections is recommended. No slope stability issues were apparent during air review. Further on ground geotechnical review recommended. Based on airphoto review, appears to be above glaciomarine clay and/or in shallow rock. Route should be checked on ground including KP 1170.1 near a basin at the headwaters of a stream. Steep cross slope. Potentially high rock cuts required. Anchors may be required. Stability of undercut overburden may require special provisions such as shotcrete and

From (KP)	To (KP)	Geotechnical Conditions	Geotechnical Comments
			anchors or cantilever shotcrete walls. Rockfall from cuts and from boulders on surface of till will require consideration during detailed design.
1170.3	1172.19	Variable terrain including areas of steep cross slope. Toward end of segment, undulating terrain. End of segment at proposed Kitimat Station. End of pipeline route will need to be adjusted to accommodate station design. Surficial Geology: No detailed mapping has been found. Based on aerial observations, glacial till veneers, possible glaciomarine clay overlying shallow bedrock. Route generally drops to south, and increased thickness of glaciomarine clay toward the south may be anticipated. Bedrock geology: Detailed mapping has not been found. Projecting from Woodsworth, Hill and van der Heyden (1985) greenschist facies diorite, tonalite.	**Difficult Area** Cross slopes and areas of marine clay that may be sensitive. Local rock fall from bedrock outcrops and boulders from till. Detailed route design including design using sections is recommended.

Notes:
1. Preliminary, based on limited ground data as discussed in report. Conditions and interpretations are subject to confirmation and further geotechnical investigations which may result in changes to the geotechnical assessments presented.
2. Assessments of feasibility of various crossing methods are preliminary and are strictly from a geotechnical point-of-view.

APPENDIX C

Terrain Hazard and Risk Summary Table C-1

LEGEND FOR TABLE C-1

The geohazard codes shown in the Geohazard Code column of Table C-1 are summarized on the risk matrices in Figures 4.1 to 4.7 of the main report.

The general format of the Geohazard Codes is #Code where:

is a sequential number
Code is a two letter code designating the type of geohazard present.

Code	**Description**
Mass Wasting	
DS	Deep-seated slides
SM	Shallow to moderately deep slides
DF	Debris Flow
RF	Rock Fall
AV	Avalanches
LS	Lateral Spreading
SE	Stream Erosion & sedimentation
ER	Wind & shallow stream or overland erosion
Settlement	
CS	Consolidation Settlement
KS	Karst induced Settlement or displacement
Seismic	
EQ	Seismic Motion
LQ	Liquefaction
Tsunamis	
TS	Tsunamis
#	Sequential number

The hazard likelihood categories (see Section 4.2.3) are shown below. These categories are used in the "Hazard Likelihood columns on Table C-1.

See Table 4.1: Hazard Likelihood Categories (Hazard Occurrence Likelihoods)

Likelihood Category	Approximate Annual Likelihood	DESCRIPTION
5	≥ 0.5	*Will likely happen regularly over the life of the Project.* Very high likelihood that the hazard could affect the pipelines and/or infrastructure in the near future and/or is affecting the pipelines at the time of study.
4	≥ 0.1	*Probably will happen over the life of the Project.* High likelihood of occurrence.
3	≥ 0.1 to 0.02	*It could happen (likely as not) over the life of the Project.* Intermediate likelihood of occurrence.
2	< 0.02	*Unlikely to happen in any given year and less likely over the life of the Project.* Low likelihood.
1	< 0.001	Very low annual likelihood of occurrence and much less likely to occur over the life of the Project. Longer term events such as major seismic events.

The consequence ratings (see Section 4.2.4) are shown below. These categories are used in the "Consequence Rating" columns on Table C-1.

See Table 4.2: Consequence Categories

CONSEQUENCE CATEGORY	DESCRIPTION
5	***Major event with extremely costly and difficult remediation*** Pipeline failure or failure of major facilities such as pumping stations that could be difficult or expensive to repair due to location or other reasons.
4	***Significant event that can be addressed but with great effort*** All other major pipeline damage events requiring replacement of pipeline segment. Failure of other infrastructure such as pumping stations that would directly affect the ability to move oil.
3	***Moderate event requiring mitigation and certainly engineering review/input*** Displacement, damage or exposure of the pipelines less likely to directly result in immediate failure (i.e., in the event of the hazard occurring, there may be sufficient time to undertake mitigative measures prior to more serious consequences). Includes in-stream exposures. Damage to pumping stations or other facilities that does not immediately cause major shutdown.
2	***Minor incident or inefficiency that may require engineering review but is easily and predictably remediated*** Coating damage, exposure or other damage not immediately resulting in a serious situation. Overland locations. Relatively easy to repair.
1	***Minor incident or inefficiency of little or no consequence*** Other low consequence outcomes. (Note that failure to suitably mitigate these outcomes could result in more serious consequences.)

The colours used in the “Risk” columns of Table C-1 are the same as used on the risk summary matrices on Figures 4.1 to 4.7 of the main report and are as follows:

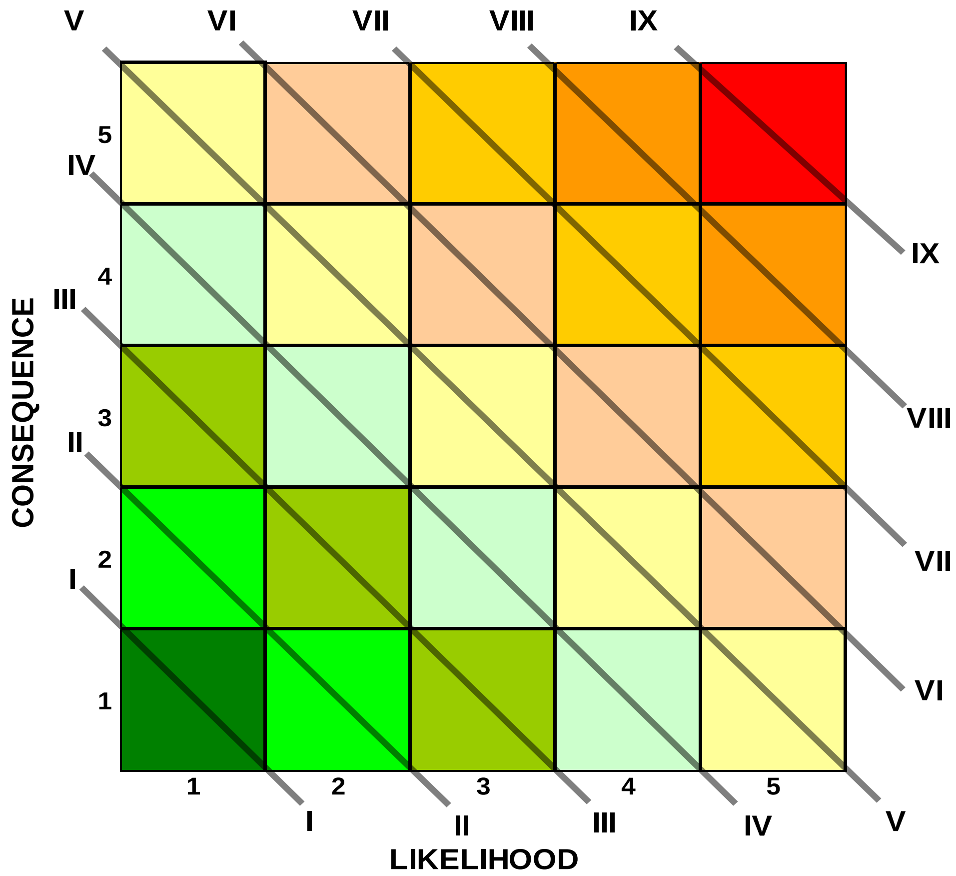


Table C-1 Terrain Hazard and Risk Summary

Location/Area KP Start - KP End	Geohazard Code	Description of Terrain	Geohazard Type(s)	Unmitigated			Potential Protection, Mitigation and Management Measures[1]	Mitigated		
				Hazard Likelihood	Consequence Rating	Risk		Hazard Likelihood	Consequence Rating	Risk
Eastern Alberta Plains										
Bruderheim Terminal to North Saskatchewan River	• 1ER	• Sandy eolian veneers and blankets.	• Wind and water erosion	5	1	5	• Re-vegetation; erosion matting; straw/hay mulching.	2	1	2
North Saskatchewan River crossing 3.6 – 4.1	• 2SM	• Slides into gully directly to north of route.	• Shallow to moderately deep slides	3	2	6	• Use routing to avoid landslides. • Design. • Ground and surface water control.	1	1	1
Southern Alberta Uplands										
Pembina River 131.5 – 131.6	• 3SE	• Meandering river incised several meters • Tending to migrate northwest, potential for cutoffs upstream and downstream	• Stream erosion (lateral migration, scour)	3	3	9	• Design to avoid stream erosion and scour.	1	1	1
Little Paddle River 163.9 – 164.0	• 4SE	• Meandering river incised several meters, minor instabilities along banks	• Stream erosion (lateral migration)	3	3	9	• Design to avoid stream erosion. • Bank reclamation methods.	1	1	1
Swan Hills southeast of Whitecourt 178.4 – 181.6	• 5DS	• Ancient deep-seated landslide that does not appear to be moving	• Deep-seated instability	1	4	4	• Control groundwater and surface water drainage. • Slope stability considerations will be incorporated in grading design.	1	2	2
Athabasca River 186.9 – 187.4	• 6SE	• Wide area of sub-channels on south side, high likelihood of reactivation, long crossing	• Stream erosion and scour	3	5	15	• Design to avoid stream erosion and scour.	1	1	1
North approach to Athabasca River 187.5 - 187.7	• 7SE	• Ridged terrain with some gullies. Local piping and blow-off failures • Deep-seated sliding to the west of PDA	• Lateral erosion to north	3	4	12	• Design to avoid stream erosion and scour. • Design slope grading based on stability. • Control groundwater and surface water drainage. • Surface water control will need to consider stability conditions to west (divert to east where possible). • Deep-seated slides avoided by routing.	1	2	2
	• 8SM		• Shallow to moderately deep slides	4	3	12		2	1	2
	• 9DS		• Deep-seated slides	3	5	15		1	1	1
Sakwatamau River 200.0 – 200.7	• 10SE	• Sub-channels on both sides. Potential for lateral erosion • Potential for meander bend cut off upstream of crossing	• Stream erosion (lateral migration)	3	3	9	• Design to avoid stream erosion.	1	1	1

Location/Area KP Start - KP End	Geohazard Code	Description of Terrain	Geohazard Type(s)	Unmitigated			Potential Protection, Mitigation and Management Measures[1]	Mitigated		
				Hazard Likelihood	Consequence Rating	Risk		Hazard Likelihood	Consequence Rating	Risk
Narrow corridor near Sakwatamau River 202.0 - 203.6	• 11SM	• Route located near edge of moderately steep slope with slides above outside bends of old channels of river and tributary	• Shallow to moderately deep slides	3	5	15	• Checks and surveys required. • Detailed groundwater and surface water control including integration with measures on Alliance RoW. • Work space on Alliance RoW Pipelines installed close to edge of Alliance RoW.	2	2	4
215.9 – 216.0	• 12SM	• Steep, narrow gully, confined channel, slopes high on both sides (potential instabilities)	• Shallow to moderate slides	3	2	6	• Design to avoid instabilities as required. • Ground and surface water control. • Grading should consider stability issues.	1	1	1
Chickadee Creek 218.9 – 219.1	• 13SE	• Tortuous meanders along creek, laterally unstable • Preliminary ratings prior to ground reconnaissance.	• Stream erosion (lateral migration)	3	3	9	• Design crossing to allow for lateral migration.	2	1	2
Two Creek 241.7 – 241.9	• 14SE	• Lateral erosion and tortuous meanders	• Stream erosion (lateral erosion)	3	3	9	• Design crossing to allow for lateral migration.	2	1	2
East approach slope to Iosegun River 258.6 to 258.8	• 15SM	• Steep slopes, shallow to moderately deep failures east and west of Rev R centerline	• Shallow to moderately deep slides	3	5	15	• Control groundwater and surface water. • Routing avoids slide areas. • Grading designed to accommodate local stability conditions.	1	1	1
	• 16ER		• Erosion on steep slopes	5	1	5		2	1	2
Iosegun River 258.8 – 260.0	• 17SE	• Soft soils, high groundwater • Sliding on banks when disturbed • Several subchannels • Highly erodible soils	• Stream erosion (lateral migration) • Sedimentation	3	3	9	• Drilling investigations. • Bank restoration methods to consider local soil conditions. • Design for lateral and possible scour erosion. • Consider consolidation settlement.	2	3	6
	• 18CS		• Consolidation settlement	4	2	8		1	2	2
East Approach to Little Smoky River 290.3 - 291.0	• 19DS	• Deep-seated sliding (terrain appears to be an erosional terrace but deep-seated slides in area). Reactivation would require a large lateral erosion event toward the east.	• Deep-seated instabilities	2	5	10	• Drilling and other further investigations. • Ground and surface water control. • Off RoW hydrotechnical measures to control lateral erosion. • Monitoring. • Bypass slide by directional drilling or other trenchless methods such as microtunnel.	1	4	4

Location/Area KP Start - KP End	Geohazard Code	Description of Terrain	Geohazard Type(s)	Unmitigated			Potential Protection, Mitigation and Management Measures[1]	Mitigated		
				Hazard Likelihood	Consequence Rating	Risk		Hazard Likelihood	Consequence Rating	Risk
Little Smoky River crossing 291.0 – 291.1	• 20SE	• Lateral erosion	• Stream erosion (lateral erosion)	4	5	20	• Design crossing to allow for lateral migration. • Off RoW hydrotechnical measures to control lateral erosion. • Directional drilling or other trenchless methods such as microtunnel.	1	3	3
West Approach Slope to Little Smoky River 291.1 - 291.9	• 21DS	• Deep-seated landslides, movement triggered by undercutting by river. Erosion along river causing renewed movement of deep seated slides. • Hazard likelihood and consequences will depend on mitigative measures used.	• Deep-seated instabilities	3	5	15	• Drilling and other further investigations. • Ground and surface water control. • Off RoW hydrotechnical measures to control lateral erosion. • Monitoring. • Bypass slide by directional drilling or other trenchless methods such as microtunnel as required.	2	4	8
Waskahigan River 317.8 – 318.4	• 22SE	• Wide floodplain, lateral migration (abandoned channels and subchannels)	• Stream erosion (lateral migration)	4	4	16	• Design crossing to avoid stream erosion.	1	1	1
Deep Valley Creek 338.6 – 339.3	• 23SE	• Wide floodplain, lateral migration and subchannels • Preliminary ratings prior to ground reconnaissance.	• Stream erosion (lateral migration)	3	3	9	• Design crossing to avoid stream erosion.	1	1	1
Tributary to Deep Valley Creek 340.5 - 341.0	• 24SE	• Tortuous meanders and lateral migration • Erosion issues on steep slopes	• Stream erosion (lateral migration, downcutting)	3	3	9	• Design to avoid stream erosion.	1	2	2
	• 25ER		• Erosion	5	2	10	• Ground and surface water control on slopes.	2	2	4
Unnamed tributary 350.7 - 350.8	• 26ER	• Erosion of banks	• Erosion	5	2	10	• Control groundwater and surface water drainage. • Grading.	2	2	4
Simonette River 359.6 – 360.1	• 27SE	• Several side-channels and abandoned channels • Preliminary ratings prior to ground reconnaissance.	• Stream erosion (lateral erosion)	3	4	12	• Conduct ground reconnaissance. • Design to avoid stream erosion.	1	2	2
Latornell River 371.6 – 372.6	• 28DS	• Possible deep-seated slide • Preliminary ratings prior to ground reconnaissance.	• Possible Deep-seated instability	2	4	8	• Control groundwater and surface water drainage. • Use routing to avoid landslides. • Design to avoid stream erosion. • Ground reconnaissance and further study.	1	2	2
	• 29SE		• Stream erosion (lateral migration)	3	3	9		1	1	1

Location/Area KP Start - KP End	Geohazard Code	Description of Terrain	Geohazard Type(s)	Unmitigated			Potential Protection, Mitigation and Management Measures[1]	Mitigated		
				Hazard Likelihood	Consequence Rating	Risk		Hazard Likelihood	Consequence Rating	Risk
West of Latornell River 373.0 – 373.2	• 30DS	• Deep-seated slide above river meander • Preliminary ratings prior to ground reconnaissance.	• Deep-seated slide.	5	4	20	• Control groundwater and surface water drainage. • Use routing to avoid landslides. • Design to avoid stream erosion. • Ground reconnaissance and further study.	1	1	1
Tributary to Smoky River 395.7 - 395.8	• 31SE	• Steep slopes • Shallow to moderately deep slides	• Stream erosion (possible downcutting, lateral migration)	4	3	9	• Design to avoid stream erosion and downcutting. • Landslides avoided by routing.	2	1	2
	• 32SM		• Shallow to moderately deep slides	4	2	8		2	1	2
Smoky River east valley wall 420.0 - 420.9	• 33DS	Slopes immediately north and south of RoW centreline have moderately deep landslides.	• Shallow to deep-seated slides	5	5	25	• Control groundwater and surface water drainage . • Landslides avoided by routing.	1	2	2
Smoky River floodplain 420.9 - 422.4	• 34SE	• River subject to significant lateral migration	• Stream erosion (lateral migration)	4	5	20	• Design to avoid stream erosion.	1	1	1
Smoky River west valley wall 422.6 - 423.6	• 35DS	• Moderately deep slide immediately to north • North of old deep-seated slide block	• Moderately deep and deep-seated instability	4	4	16	• Control groundwater and surface water drainage. • Landslides avoided by routing.	2	2	4
Gold Creek 431.6 – 432.1	• 36SM	• Deeply incised, meandering channel • Shallow to moderately deep slides • Moderately steep slopes about 30 m high • Erosion • Preliminary ratings prior to ground reconnaissance.	• Shallow to moderately deep slides	4	4	16	• Conduct reconnaissance and avoid landslides by routing. • Design to avoid stream erosion. • Control groundwater and surface water drainage. • Slope stability considerations to be incorporated in grading design.	2	1	2
	• 37ER		• Erosion on slope	5	2	10		3	1	3
	• 38SE		• Stream erosion (lateral migration)	3	3	9		1	2	2
Big Mountain Creek 434.9 - 435.7	• 39SM	• Shallow to moderately deep sliding • Steep vertical exposure just south of crossing • Creek incised and meandering (potential for stream erosion) • Erosion • Preliminary ratings prior to ground reconnaissance.	• Shallow to moderately deep slides	4	4	16	• Conduct reconnaissance and avoid landslides by routing. • Design to avoid stream erosion. • Control groundwater and surface water drainage. • Slope stability considerations to be incorporated in grading design.	2	2	4
	• 40ER		• Erosion on slope	5	2	10		3	1	3
	• 41SE		• Stream erosion (lateral migration)	3	2	6		1	1	1
Bald Mountain Creek	• 42SM	• Moderately deep failures south of the crossing (about 200 m to the south)	• Shallow to moderately deep slides	4	4	16	• Conduct reconnaissance and avoid landslides by routing.	2	1	2

Location/Area KP Start - KP End	Geohazard Code	Description of Terrain	Geohazard Type(s)	Unmitigated			Potential Protection, Mitigation and Management Measures[1]	Mitigated		
				Hazard Likelihood	Consequence Rating	Risk		Hazard Likelihood	Consequence Rating	Risk
445.9 - 446.0	• 43SE	• Route appears to be crossing a moderately deep-seated landslide on the east side of the creek, both sides possibly unstable	• Stream erosion (downcutting, lateral migration)	3	3	9	• Design to avoid stream erosion. • Control groundwater and surface water drainage. • Slope stability considerations to be incorporated in grading design.	1	1	1
	• 44ER	• Meandering creek, lateral erosion • Erosion	• Erosion on slope	5	2	10		3	1	3
Pinto Creek meander bend 469.9 - 470.1	• 45DS	• Deep-seated slide triggered lateral channel migration (meander bend of Pinto Creek close to south)	• Deep-seated instability	5	5	25	• Avoid by routing farther north. • Control groundwater and surface water drainage.	1	1	1
Pinto Creek 472.4 – 473.7	• 46DS	• Possible slides • Preliminary ratings prior to ground reconnaissance.	• Potential slides (deep seated)	4	5	20	• Conduct ground reconnaissance. • Avoid slides by routing.	1	2	2
Wapiti River area 494.7 – 495.3	• 47DS	• Narrow area ("neck") with apparent deep-seated slide in valley-fill clay on north side and shallow slides in rock and glaciolacustrine clay on south side	• Moderately deep-seated instabilities	3	3	9	• Use routing and grading to avoid landslides.	2	1	2
Rocky Mountains										
566.1 - 579.5	• 48SM	• Several areas of rock cuts in the ends of ridges striking diagonally across RoW (potential for shallow sliding in soil veneers or bedrock slides)	• Shallow slides	3	2	6	• Suitable Design.	2	1	2
Quintette Creek 574.9 - 575.5	• 49SE	• Alluvial fan, potential for avulsion	• Stream erosion (avulsion)	3	3	9	• Design to avoid stream erosion.	2	1	2
577.8 - 579.2	• 50DF	• Potential for stream erosion • Potential for debris flows	• Debris flows	4	3	12	• Use routing or design to avoid stream erosion and debris flows.	2	2	4
	• 51SE		• Stream erosion (lateral migration)	3	3	9		1	1	1
Five Cabin Creek 580.3 - 581.1	• 52SE	• Large alluvial fan subject to major avulsion events	• Stream erosion (avulsion)	5	4	20	• Design to avoid stream erosion. • Possible route change to avoid problem area.	2	2	4
Kinuseo Creek near alignment 586.0- 588.1	• 53SE	• Flat-lying topography, historical high mobility (potential for lateral migration) on alluvial fan	• Stream erosion (lateral migration)	3	3	9	• Design to avoid stream erosion.	1	1	1
Tributary of Murray River 597.9 - 597.4	• 54SM	• Steep valley walls and terrace complexes • Possible old failures, including an apparent old slump block on the east side • Debris-mantled slopes prone to failure if disturbed	• Shallow to moderately deep slides	3	3	9	• Control groundwater and surface water drainage. • Landslides avoided by routing. • Grading to consider stability conditions.	2	1	2
Murray River 598.3 - 600.2	• 55KS	• Potential for karst (limestone, no karst identified to date)	• Karst-induced settlement or displacement	2	3	6	• Use routing or design to avoid karst if required. • Design.	2	1	2
Hook Creek area	• 56SM	• Minor surface failures on approach slopes (stream undercutting)	• Shallow slides	4	2	8	• Design of grading.	2	1	2

Location/Area KP Start - KP End	Geohazard Code	Description of Terrain	Geohazard Type(s)	Unmitigated			Potential Protection, Mitigation and Management Measures[1]	Mitigated		
				Hazard Likelihood	Consequence Rating	Risk		Hazard Likelihood	Consequence Rating	Risk
602.0- 603.2	• 57SE	• Lateral migration into high banks	• Stream erosion (downcutting, lateral migration)	4	3	12	• Design to avoid stream erosion.	2	2	4
614.0 – 614.4	• 58DF	• Potential for debris flows	• Debris flows	4	3	12	• Design to avoid debris flows.	2	1	2
617.0 - 623.5	• 59AV	• Locally steep terrain, possibly with wet organics and steep side hills • Potential for shallow slides in muskeg during construction • Local avalanches • Potential for karst (limestone)	• Avalanches	5	3	15	• Design to avoid or control avalanches, stream erosion, karst and rockfall. • Design and routing to control shallow slides.	2	1	2
	• 60SM		• Shallow slides	5	2	10		1	1	1
	• 61KS		• Karst-induced settlement or displacement	2	3	6		1	1	1
621.2-622.6	• 62AV	• Potential for avalanches and possibly rockfall during design and operations	• Avalanches	5	3	15	• Design to avoid or control avalanches and rockfall.	2	1	2
	• 63RF		• Rockfall	4	4	16		2	2	4
Headwaters of Hominka River, pass through Rockies 625.2 – 626.6	• 64SM	• Short distance north of the area may be karstic limestone. Karst identified to south.	• Shallow to moderately deep slides	3	3	9	• Route has been selected to miss apparent problem area.	1	1	1
	• 65KS		• Karst-induced settlement or displacement	4	3	12		1	1	1
627.6 – 629.0	• 66CS	• Frequent organic deposits (muskeg), some on gentle to moderate slopes • Artesian groundwater conditions with muskeg mounds	• Consolidation settlement	4	3	12	• Design for consolidation settlement. • Avoid large springs by routing.	2	1	2
	• 67ER		• Erosion	5	2	10		1	1	1
Tributaries to Missinka River 632.0 – 636.8	• 68SE	• Tributaries to Missinka River at KP 632.0, 633.0, 635.0, 635.2, 636.4 and 636.8 that may be subject to high flows and/or debris flows	• Stream erosion	4	3	12	• Design to avoid/mitigate stream erosion and debris flows.	2	1	2
	• 69DF		• Debris flows	3	3	9		2	1	4
634.6 – 637.2	• 70SM	• Frequent wet surface soils prone to sliding in cuts • Avalanche chutes at KP 635.8 and 636.6	• Shallow slides	5	2	10	• Limit surface disturbances in critical areas. • Control groundwater and surface water drainage. • Slope stability considerations will be incorporated in grading design. • Design to avoid or mitigate avalanches as required.	2	2	4
	• 71AV		• Avalanches	3	3	9		2	1	2
640.6 - 641.4	• 72SM	• Gullied till, outwash and glaciolacustrine materials prone to shallow sliding in cuts	• Shallow slides	5	2	10	• Limit surface disturbances in critical areas. • Control groundwater and surface water drainage. • Slope stability considerations will be incorporated in grading design.	2	2	4
Missinka River valley 641.6 - 666.6	• 73SM	• Glaciolacustrine deposits, moderately steep slopes, known stability problems on low cuts from 641.6 – 645.8 and 646.2 – 666.6	• Shallow slides	5	2	10	• Slope stability considerations will be incorporated in grading design.	2	1	2

Location/Area KP Start - KP End	Geohazard Code	Description of Terrain	Geohazard Type(s)	Unmitigated			Potential Protection, Mitigation and Management Measures[1]	Mitigated		
				Hazard Likelihood	Consequence Rating	Risk		Hazard Likelihood	Consequence Rating	Risk
	• 74ER		• Erosion	4	2	8	• Control groundwater and surface water drainage. • Design to control sedimentation. • Landslides avoided by routing.	2	2	4
Interior Plateau										
Parsnip River area 670.4 – 672.8	• 75SM	• Glaciolacustrine deposits, potentially unstable • Frequent organics (muskeg) and soft sediment	• Shallow to moderately deep slides	4	2	8	• Landslides avoided by routing. • Design for consolidation settlement. • Control groundwater and surface water drainage.	1	1	1
	• 76CS		• Consolidation settlement	3	2	6		2	1	2
Parsnip River 670.8 - 671.4	• 77SE	• Historical and recent lateral migration	• Stream erosion (lateral migration)	4	5	20	• Design to avoid stream erosion.	1	1	1
679.2 – 685.2	• 78SM	• Poorly drained wet terrain with moderate slopes • Shallow slides in cuts • Erosion	• Shallow to moderately deep slides	4	2	8	• Landslides avoided by routing. • Control groundwater and surface water drainage. • Cut and fill design. • Design to control sedimentation.	2	1	2
	• 79SE		• Sedimentation	4	2	8		2	1	2
	• 80ER		• Erosion	5	1	5		2	1	2
687.0 – 698.0	• 81SM	• Glaciolacustrine soils with sand seams in low-lying areas are known to have stability problems on low cuts • Route is adjacent to Chuchinka Creek (potential for stream erosion)	• Shallow to moderately deep slides	4	2	8	• Limit surface disturbances in critical areas. • Slope stability considerations will be incorporated in grading design. • Design to avoid stream erosion. • Surface and ground water control.	2	1	2
	• 82SE		• Stream erosion (lateral migration and avulsion)	3	3	9		1	1	1
	• 83ER		• Erosion	5	1	5		2	1	2
Angusmac Creek 710.2 – 710.8	• 84SM	• Potential for lateral migration across wide floodplain • Moderately steep gullied slopes to east and west, potential instabilities	• Shallow to moderately deep slides	5	2	10	• Design to avoid stream erosion. • Using routing to avoid instabilities. • Design of grading. • Surface and ground water control.	2	1	2
	• 85ER		• Erosion on slopes	5	1	5		3	1	3
	• 86SE		• Stream erosion (lateral migration)	4	4	16		1	2	2
Crooked River 718.0- 718.6	• 87SE	• Highly mobile river with wide floodplain (potential for lateral migration) • Poorly drained organic terrain (718.0 – 718.6)	• Stream erosion (lateral migration)	4	3	12	• Design to avoid stream erosion. • Design for consolidation settlement as required.	1	1	1
	• 88CS		• Consolidation settlement	3	2	6		2	1	2

Location/Area KP Start - KP End	Geohazard Code	Description of Terrain	Geohazard Type(s)	Unmitigated			Potential Protection, Mitigation and Management Measures[1]	Mitigated		
				Hazard Likelihood	Consequence Rating	Risk		Hazard Likelihood	Consequence Rating	Risk
North of Slender Lake 739.0-740.9	• 89CS	• Frequent organics (muskeg)	• Consolidation settlement	3	2	6	• Design for consolidation settlement as required.	2	1	2
Muskeg River area 747.2 – 748.7	• 90SE	• Potential for lateral migration	• Stream erosion (lateral migration)	3	4	12	• Design to avoid stream erosion.	1	2	2
Salmon River area 762.5 – 763.8	• 91SE	• Evidence of shallow sliding and/or groundwater piping and gully erosion (incised creeks) on west side • Highly mobile river with 450 m wide floodplain • Frequent debris jams	• Stream erosion (lateral migration)	5	5	25	• Design to avoid stream erosion. • Landslides avoided by routing. • Slope stability considerations to be incorporated in grading design. • Ground and surface water control.	2	2	4
	• 92SM		• Shallow to moderately deep slides	4	2	8		2	1	2
	• 93ER		• Erosion on slopes	5	2	10		2	1	2
Stuart River 821.0 - 822.0	• 94DS	• Very extensive deep-seated slides in glaciolacustrine clays extend far to the south on east and west approaches • Moderately deep-seated slide along lower valley wall on west side of river. Involves lowest terrace • Gullies are dry and not eroding	• Deep-seated instabilities	5	5	25	• Control groundwater and surface water drainage. • Design to avoid stream erosion. • Use routing or design to avoid instabilities. • Trenchless crossing method to avoid slide on west side.	1	2	2
	• 95SM		• Shallow to moderately deep slides	5	4	20		1	1	1
Endako River 929.2 – 929.8	• 96CS	• Potential for consolidation settlement in vicinity of CN Rail embankment to east • Organic deposits near river • Organic veneers west of river	• Consolidation Settlement	4	4	16	• Design for consolidation settlement.	2	2	4
Klo Creek valley 975.2 – 975.4	• 97SE	• Very steep approach slope • Mobile channel (potential for lateral migration) • Moderately steep slopes with potential for instability (existing small failures identified north and south of route) • Fine-grained soils in valley bottom • Parts of east approach slope have groundwater blow-off failures • Small failures on west slope due to stream erosion in glaciolacustrine sediments	• Stream erosion (lateral migration)	5	3	15	• Slope stability considerations to be incorporated in grading design. • Control groundwater and surface water. • Design to avoid stream erosion. • Design to control erosion. • Ground and surface water control. • Routing to avoid slide on west side.	1	2	2
	• 98SM		• Shallow to moderately deep slides	4	3	12		1	1	1
	• 99ER		• Erosion on slopes	5	2	10		2	1	2
Lamprey Creek area 1018.3 - 1019.3	• 100SM	• East valley wall moderate to steep and about 80 m high, slide evident near route	• Shallow to moderately deep slides	5	3	15	• Grade slopes. • Design to avoid landslides. • Ground and surface water control.	1	2	2

Location/Area KP Start - KP End	Geohazard Code	Description of Terrain	Geohazard Type(s)	Unmitigated			Potential Protection, Mitigation and Management Measures[1]	Mitigated		
				Hazard Likelihood	Consequence Rating	Risk		Hazard Likelihood	Consequence Rating	Risk
Cedric Creek 1025.6 - 1026.3	• 101SM	• Incised channel • Potential for shallow sliding	• Shallow to moderately deep slides	3	2	6	• Landslides avoided by routing. • Slope stability considerations to be incorporated in grading design. • Design to avoid stream erosion. • Ground and surface water control.	1	1	1
	• 102SE		• Stream erosion	3	3	9		1	1	1
1032.3 – 1035.3	• 103SM	• Shallow soils on moderately steep , bedrock-controlled slopes (potential for shallow to moderately deep sliding along route) • Slopes become steeper north of RoW • Erosion	• Shallow to moderately deep slides	3	3	9	• Landslides and excessively steep sidehills avoided by routing. • Narrow graded area with workspace on road.	2	2	4
	• 104ER		• Erosion	4	3	12		2	1	2
Tributary to Gosnell Creek 1044.3	• 105SE	• Potential for stream erosion (avulsion) and debris torrents	• Stream erosion (avulsion)	4	5	20	• Design to avoid stream erosion and debris flows.	2	2	4
	• 106DF		• Debris flows	4	4	16		2	2	4
1050.2 – 1055.8	• 107DF	• RoW at the base of steep slopes to south • Avalanche/debris flow run-out zones above route	• Debris flows	3	4	12	• Design to avoid or control debris flows.	2	2	4
Gosnell Creek 1058.8 – 1059.1	• 108SE	• Relatively mobile channel (potential for lateral migration) • Frequent debris jams	• Stream erosion (lateral migration)	3	3	9	• Design to avoid stream erosion.	1	1	1
1066.1 - 1067.3	• 109SE	• Alluvial fan • Potential for stream erosion (avulsion) and debris torrents	• Stream erosion (avulsion, downcutting)	3	3	9	• Design to avoid stream erosion and debris flows.	1	2	2
	• 110DF		• Debris flows	3	3	9		1	2	2
Coast Mountains										
1068.3 – 1172.2	• 111EQ	• Seismic motion • Movement of slides induced by seismic motion	• Seismic motion	1	5	5	• Pipeline and ancillary structures must be designed for appropriate seismic forces. • For overland pipelines, seismic motions are not typically an issue. • Seismic-induced sliding will be mitigated through design process for slides discussed in other entries.	1	3	3
East approach slope to Burnie and Clore River valleys 1070.6 to 1071.1	• 112SM	• Shallow slide north of Rev R. • Erosion on steep terrain	• Shallow slide	4	3	12	• Avoided by routing. • Ground and surface water control.	1	1	1
	• 113ER		• Erosion	5	2	10		2	1	2

Location/Area KP Start - KP End	Geohazard Code	Description of Terrain	Geohazard Type(s)	Unmitigated			Potential Protection, Mitigation and Management Measures[1]	Mitigated		
				Hazard Likelihood	Consequence Rating	Risk		Hazard Likelihood	Consequence Rating	Risk
1072.4 – 1072.8 Clore River	• 114SE	• Lateral migration	• Stream erosion (lateral migration)	5	4	20	• Design crossing to accommodate lateral erosion.	1	1	1
Tributary to Clore River and adjacent areas 1079.8- 1079.9	• 115SM	• Steep bedrock-controlled slopes • Rockfall areas identified (primarily east of KP 1079.4) • Two avalanche tracks are present very near the route (southwest and southeast) • Shallow slides in colluvium • Channel is confined with potential for debris torrents • Avalanches and debris flows are parallel to pipeline route.	• Shallow to moderately deep slides	5	2	10	• Design to avoid or control rockfall and avalanches. • Design to avoid debris flows. • Landslides avoided by routing. • Control groundwater and surface water.	1	1	1
	• 116DF		• Debris flows	3	2	6		1	1	1
	• 117AV		• Avalanches	4	2	8		1	2	2
	• 118RF		• Rockfall	5	4	20		1	2	2
West Portal Hoult Tunnel 1086.6 – 1086.9	• 119AV	• Steep valley walls with potential for avalanches and rockfall on east side • Avalanches and debris flows are parallel to pipeline route.	• Avalanches	4	2	8	• Use routing to avoid avalanches and rockfall.	1	1	1
	• 120RF		• Rockfall	3	4	12		1	1	1
Hoult Creek and upper Kitimat River valley 1086.9 - 1098.3 and 1099.3 to 1101.3	• 121DF	• Northwest side of Hoult Creek valley has several watercourse crossings in steep gullies and ravines (subject to high flows, debris flows or avalanches) • Downstream of KP 1087, Hoult Creek is highly mobile due to avalanche and debris flow loading • Rockfall could occur from steep ravine walls in some areas • Possible avalanches from southeast side of valley (could re-direct Hoult Creek) • Groundwater blow-off failures have occurred locally during logging road construction • Slides in logging road fills have occurred in a few areas • Fan/cone complex with evidence of avalanches at KP 1090.7–1091.7 and 1092.3–1093.0	• Debris flows	4	4	16	• Detailed geotechnical and civil design based on detailed topography and cross sections. • Control groundwater and surface water drainage. • Design to control sedimentation. • Design to avoid or control rockfall and avalanches. • Landslides avoided by routing. • Design to avoid debris flows and stream erosion.	2	2	4
	• 122RF		• Rockfall	3	3	9		2	1	2
	• 123SE		• Stream erosion (downcutting, lateral migration) • Sedimentation	4	3	12		1	1	1
	• 124SM		• Shallow to moderately deep slides	4	3	12		1	1	1
	• 125AV		• Avalanches	5	4	20		1	2	2
Hunter Creek 1098.3 - 1099.3	• 126SE	• Active alluvial fan prone to major avulsion and debris flows and torrents • Several small shallow slides in surface soils along terrace fronts (due to creek undercutting)	• Stream erosion (avulsion, downcutting)	5	5	25	• Design to avoid stream erosion and debris flows. • Landslides avoided by routing.	1	1	1
	• 127DF		• Debris flows	5	5	25		1	1	1
	• 128SM		• Shallow to moderately deep slides	4	3	12		1	1	1
1101.3 - 1102.3	• 129SE	• RoW crosses several active alluvial fans. • Potential for stream erosion (avulsion), debris flows and debris torrents	• Stream erosion (avulsion)	4	3	12	• Design to avoid stream erosion and debris flows.	1	2	2
	• 130DF		• Debris flows	3	4	12		1	2	2
Upper Kitimat River valley 1101.3 - 1119.3	• 131SM	• Steep gullied slopes, potentially unstable • Evidence of avalanches • Evidence of shallow to moderately deep slides in shallow colluvium over bedrock	• Shallow to moderately deep slides	4	4	16	• Detailed geotechnical and civil design based on detailed topography and cross sections.	2	1	2
	• 132AV		• Avalanches	4	3	12		2	2	4

Location/Area KP Start - KP End	Geohazard Code	Description of Terrain	Geohazard Type(s)	Unmitigated			Potential Protection, Mitigation and Management Measures[1]	Mitigated		
				Hazard Likelihood	Consequence Rating	Risk		Hazard Likelihood	Consequence Rating	Risk
	• 133SE	• Several watercourse crossings in steep gullies and ravines • Some streams subject to high flows and debris torrents • Isolated rockfall potential from bluffs • Groundwater blow-off failures have occurred locally during logging road construction	• Stream erosion (downcutting) • Sedimentation	3	3	9	• Control groundwater and surface water drainage. • Design to control sedimentation. • Landslides avoided by routing. • Design to avoid or control avalanches and rockfall. • Design to avoid stream erosion and debris flows.	2	1	2
	• 134DF		• Debris flows	5	4	20		1	2	2
	• 135RF		• Rockfall	4	5	20		1	2	2
1115.9	• 136SE	• Kitimat River eroding laterally toward the logging road aided by groundwater piping of sediments in the river bank	• Stream erosion (lateral migration)	5	4	20	• Route avoids problem area.	1	1	1
Chist Creek 1122.8 - 1123.8	• 137SE	• Extensive lateral migration, particularly south of PDA • Shallow slides along actively-eroding terrace fronts (related to undercutting) • Potential for lateral erosion of creek north of existing road west of bridge.	• Stream erosion (lateral migration)	5	4	20	• Design to avoid/reduce stream erosion. • Possible riprap on outside bend north of bridge.	1	2	2
Cecil Creek 1131.0 – 1131.8	• 138ER	• Steep eroded terrace fronts and valley walls	• Erosion on slope	5	2	10	• Control groundwater and surface water drainage. • Consider erosion in design of grading. • Ground reconnaissance of south side.	2	1	2
1135.6 – 1137.2	• 139SM	• Sliding and erosion in glaciomarine sediments	• Shallow to moderately deep sliding	5	4	20	• Avoided by routing north around area and along edge of rock and till on Iron Mountain.	1	1	1
	• 140ER		• Erosion	5	3	15		1	1	1
1136.2	• 141RF	• Waterfall and rockfall	• Rockfall	5	3	15	• Design and routing.	2	2	4
Eastern flank on Iron Mountain 1135.3 – 1143.3	• 142LS	• Potential for lateral spreading and induced sliding in sensitive clays in localized areas below about 200 m elevation. • Borehole R02 encountered 0.2 m of sensitive marine clays at a depth of 44 m.	• Lateral spreading or deep-seated sliding	1	5	5	• Design and route to avoid areas prone to lateral spreading. • Possible reroute on rock of Iron Mountain flank to the west. • Alternate reroute along ridge in middle of Kitimat River Valley. • Landslides avoided by routing. • Additional ground and drilling investigation.	1	1	1
	• 143SM		• Shallow to moderately deep slides	3	3	9		1	1	1
Southeast flank of Iron Mountain 1142.6 – 1144.1	• 144RF	• Recent rockfall at about KP 1143.3	• Rockfall	5	3	15	• Design to avoid or control rockfall.	2	1	2
Wedeene River area 1143.3 – 1146.8	• 145DS	• Buried and exposed bedrock (profile unknown) • Deep-seated slides likely in sensitive glaciomarine clay.	• Deep-seated instabilities	5	4	20	• Control groundwater and surface water.	1	1	1

Location/Area KP Start - KP End	Geohazard Code	Description of Terrain	Geohazard Type(s)	Unmitigated			Potential Protection, Mitigation and Management Measures[1]	Mitigated		
				Hazard Likelihood	Consequence Rating	Risk		Hazard Likelihood	Consequence Rating	Risk
	• 146SM	• Shallow to moderately deep slides including retrogressive sliding, groundwater piping and erosion. • Potential for lateral spreading and induced sliding in sensitive clays in localized areas below about 200 m elevation. Thicknesses in excess of 12 m of sensitive clays were found in a borehole to the south of the Wedeene Crossing • Borehole R03 encountered 0.1 m of sensitive clay at a depth of 9 m and 12 m of sensitive clays at 21.5 through 33.5 m depth.	• Shallow to moderately deep slides	3 varies	3	9	• Conduct ground reconnaissance. • Use routing and crossing design to avoid landslides. • Use routing and crossing design to avoid sensitive clays. • Further investigation required for sensitive clays.	2	2	4
	• 147LS		• Lateral spreading or deep-seated sliding	1	5	5		1	1	1
1146.8 – 1150.3	• 148LS	• Potential for lateral spreading and induced sliding in sensitive clays in localized areas below about 200 m elevation near the Little Wedeene River	• Lateral spreading or deep-seated sliding	1	5	5	• Use routing and crossing design to avoid areas prone to lateral spreading. • Possible reroute along the rock slopes to the west. • Further investigation required for sensitive clays.	1	1	1
	• 149SM		• Shallow to moderately deep slides	3	3	9		1	1	1
Little Wedeene River 1148.3 - 1149.3	• 150SM	• Terraced glaciofluvial and glaciomarine deposits • Possibility of glaciomarine deposits will need further investigation. • Shallow instabilities identified (related to river undercutting) • Mobile channel (potential for lateral migration)	• Shallow to moderately deep slides	5	4	20	• Control groundwater and surface water drainage. • Design to avoid stream erosion. • Landslides avoided by routing. • Further investigations relative to design.	1	1	1
	• 151SE		• Stream erosion (lateral migration)	3	4	12		1	1	1
1150.3 – 1172.2	• 152LS	• Potential for lateral spreading and induced sliding in sensitive clays in localized areas below about 200 m elevation. • No known lateral spreading failures close to the pipeline route	• Lateral spreading or deep-seated sliding	1	5	5	• Use routing and crossing design to avoid areas prone to lateral spreading. • Possible reroute using a ridge in the Kitimat River Valley east of the current alignment. • Further investigations required for sensitive clays.	1	1	1
	• 153SM		• Shallow to moderately deep slides	3	3	9		1	1	1
West of Kitimat River 1153.8 – 1155.3	• 154SE	• RoW potentially susceptible to lateral erosion at the outside bend of Kitimat River	• Stream erosion (lateral migration)	3	3	9	• Design to avoid stream erosion.	1	1	1
1158.6 – 1159.8	• 155SE	• RoW potentially susceptible to lateral erosion at the outside bend of Kitimat River • Potential for lateral spreading to be further investigated	• Stream erosion (lateral migration)	3	5	15	• Design to avoid stream erosion. • Further investigations.	2	2	4
Anderson Creek 1163.5 - 1164.3	• 156SE	• Failure of existing dikes and stream training installations to be further considered –might result in lateral erosion	• Stream erosion (lateral erosion)	2	5	10	• Design to avoid lateral erosion.	1	1	1

Location/Area KP Start - KP End	Geohazard Code	Description of Terrain	Geohazard Type(s)	Unmitigated			Potential Protection, Mitigation and Management Measures[1]	Mitigated		
				Hazard Likelihood	Consequence Rating	Risk		Hazard Likelihood	Consequence Rating	Risk
1164.3 – 1164.9	• 157CS	• Potential for consolidation settlement due to presence of fine-grained, compressible soils.	• Consolidation settlement	3	5	15	• Design for consolidation settlement or use routing to avoid area. • Design for liquefaction or route around area.	2	2	4
	• 158LQ	• Potential for liquefaction due to seismic motion	• Liquefaction	1	5	5		1	2	2
Moore Creek area 1165.0 – 1165.2	• 159DF	• Deeply incised channel in bedrock • Potential for debris torrents	• Debris flows	3	3	9	• Design to avoid debris flows.	1	1	1
West side of Kitimat Arm 1167.1 - 1171.3	• 160SM	• Steeply sloping terrain, bedrock-controlled, numerous small gullies or ravines and shallow surface slides and rockfall • Large rockfall area south of RoW from KP 1170.0 – 1170.3 • Eroded alluvial and colluvial materials • Susceptible to debris torrents from adjacent gully systems • Stream at 1169.1 may be subject to debris flows or high flows • Rockfall from boulders in till on slopes	• Shallow to moderately deep slides	5	3	15	• Design to avoid or control rockfall. • Design to avoid debris flows and stream erosion. • Control groundwater and surface water. • Slope stability considerations to be incorporated in grading design.	2	2	4
	• 161RF		• Rockfall	5	4	20		2	2	4
	• 162DF		• Debris flows	4	4	16		1	1	1
	• 163SE		• Stream erosion (downcutting)	3	3	9		1	1	1
Kitimat Terminal 1172.2	• 164TS	• Possibility of tsunami affecting docking facilities	• Tsunami	• Under study			• Under study.	• Under study		
Kitimat Terminal 1172.2	• 165SM	• Potential for shallow to deep-seated landslides in fine-grained glaciomarine soils • Potential for lateral spreading and consolidation settlement in fine-grained soils • Debris flow potential from small, high-gradient streams • Potential for rockfall from steep, bedrock-controlled slopes	• Shallow to moderately deep slides	3	5	15	• Facilities to be located outside of extents of significant fine-grained soils. • Design to avoid debris flows. • Design to avoid or control rockfall. • Detailed investigations have been done to facilitate detailed design.	2	2	4
	• 166DS		• Deep-seated instabilities	3	5	15		1	1	1
	• 167LS		• Lateral spreading	3	5	15		1	1	1
	• 168CS		• Consolidation settlement	2	4	8		1	2	2
	• 169DF		• Debris flows	3	3	9		1	1	1
	• 170RF		• Rockfall	3	3	9		1	2	2

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Acid Rock Drainage and Metal Leaching Field Investigation Enbridge Northern Gateway Project

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Northern Gateway Pipelines Inc.

Calgary, AB

Submitted by:

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ABA	Acid Base Accounting
AMEC	AMEC Earth and Environmental, a Division of AMEC Americas Limited
AP	Acid Potential
ARD	Acid Rock Drainage
ARD/ML	Acid Rock Drainage and Metal Leaching
BC	British Columbia
BC MEMPR	British Columbia Ministry of Energy, Mines, and Petroleum Resources
BCGS	British Columbia Geological Survey
CCME	Canadian Council of Ministers of the Environment
Ck	Creek
Fm	Formation
GIS	Geographic Information System
Gp	Group
GSC	Geologic Survey of Canada
ICP	Inductively Coupled Plasma Mass Spectrometry
KP	Kilometre Post
Lk	Lake
ML	Metal Leaching
NAD 83	North American Datum of 1983
NAG	Not Acid Generating
NGR	National Geochemical Reconnaissance
NNP	Net Neutralization Potential
NP	Neutralizing Potential
NPR	Net Potential Ratio
NW	Northwest
PAG	Potentially Acid Generating
Rev	Revision
RGS	Regional Geochemical Survey
RoW	Right of Way
SE	Southeast
SW	Southwest
WRA	Whole Rock Analysis
XRF	X-ray Fluorescence

GLOSSARY

Acid Base Accounting (ABA)	An analytical technique applied to mine wastes and geologic materials that determine the potential acidity from sulfur analysis versus the neutralization potential. It is used to predict the potential of that material to be acid producing or acid neutralizing.
Acid Potential (AP)	The ability of a rock or geologic material to produce acid leachates; may also be referred to as acid generation potential or AGP.
Acid Rock Drainage (ARD)	A low pH, metal-laden, sulfate-rich drainage that occurs during land disturbance where sulfur or metal sulfides are exposed to atmospheric conditions. It forms under natural conditions from the oxidation of sulfide minerals and where the acidity exceeds the alkalinity. Non-mining exposures, such as along highway road cuts, may produce similar drainage. Also known as acid mine drainage (AMD) when it originates from mining areas.
Inductively Coupled Plasma Mass Spectrometry (ICP)	A type of mass spectrometry that is highly sensitive and capable of the determination of a range of metals and several non-metals at concentrations below one part in 10^{12}. It is based on an inductively coupled plasma as a method of producing ions (ionization) combined with a mass spectrometer as a method of separating and detecting the ions. ICP is also capable of monitoring isotopic speciation for the ions of choice.
Metal Leaching (ML)	The process whereby acidic waters formed by sulphide oxidation may break down other metal-bearing minerals and cause the release of dissolved metals.
Net Neutralization Potential (NNP)	NNP = NP – AP. The first 20 kg $CaCO_3$/t of a sample is considered to be 'unavailable'. Any sample with an NNP less than 20 is considered to have no capacity for acid neutralization.
Net Potential Ratio (NPR)	The balance between acid production and neutralization is expressed as the ratio of neutralizing potential (NP) to acid potential (AP).
Neutralizing Potential (NP)	The amount of alkaline or basic material in rock or soil materials that is estimated by acid reaction followed by titration to determine the capability of neutralizing acid from exchangeable acidity or pyrite oxidation. May also be referred to as acid neutralization potential or ANP.
Whole rock analysis (WRA)	Determines the major element composition of a rock in terms of weight percent oxide via lithium metaborate fusion. WRA is a useful tool for determining rock type, and when used in conjunction with trace metals analysis, WRA can help to highlight concentrations of elevated metals.

IMPORTANT NOTICE

EXECUTIVE SUMMARY

AMEC Earth and Environmental, a Division of AMEC Americas Limited (AMEC) was retained by Enbridge Pipelines Inc. (Enbridge) to investigate the potential for acid rock drainage (ARD) prone bedrock to be encountered during the installation of two parallel approximately 1172 km long oil and condensate pipelines (the pipelines). The pipelines are proposed to be installed within a corridor that extends from Kitimat, British Columbia to Bruderheim, Alberta.

In order to provide an initial assessment of potential ARD prone areas, the geology underlying the pipeline route was evaluated for its potential to contain sulphides. GIS was used to integrate the data and interrogate datasets using three different models of sulphide occurrence. Those models are:

1. Known sulphide mineralization (such as the copper-silver Equity Silver mine);
2. Known pyrite-bearing lithologies (such as the Muskiki shale), and;
3. Geology permissive for sulphide mineralization or pyritic lithologies.

Based on the results of the GIS-based study and the site visits conducted in the summer of 2006, the following 9 sites are directly on the proposed alignment or within lithologies known to cross the alignment. These sites have a high potential to be a source of ARD based on laboratory determined ARD potential, the spatial extent of the unit, and on the current proposed alignment of the pipelines. These sites are recommended for consideration for further investigation during detailed engineering and design.

Site	Approximate KP Location (Rev R)*	
	From	To
Kitimat Terminal	1172 (end of alignment)	includes all Terminal facilities
Nimbus Ridge	1088	1089
Hoult MINFILE	1081	1082
Clore Ridge	1073	1079
Equity Silver and Foxy Creek	957	966
Misinchinka Gp	654	667
Miette Fm	637.5	647
Besa River Fm	601	605.5

* The KP locations for these sites have been extrapolated in relation to the route and geology. The KP locations are not considered definitive boundaries. The KP locations were revised to the Rev R alignment in October 2009.

Based on the results of this investigation, the following recommendations are made:

- Detailed investigations should be conducted of potential ARD sites as part of detailed engineering and design. Detailed investigations may include geological mapping, higher density ARD sampling or shallow drilling.

- Where possible, efforts should be made to minimize the disturbance of bedrock associated with sites identified as having ARD potential.

1.0 INTRODUCTION

AMEC Earth and Environmental, a Division of AMEC Americas Limited (AMEC) was retained by Enbridge Pipelines Inc. (Enbridge) to investigate the potential for acid rock drainage (ARD) prone bedrock to be encountered during the installation of two parallel approximately 1172 km long petroleum and condensate pipelines (the pipelines). The pipelines are proposed to be installed within a corridor that extends from Kitimat, British Columbia to Bruderheim, Alberta.

Acid Rock Drainage (ARD) occurs when minerals containing high concentrations of metals or sulphides are exposed to physical and chemical weathering, producing acidic metal-rich waters that may severely impact streams and the surrounding environment.

The purpose of this document is to summarize the investigative work conducted by AMEC Earth & Environmental (AMEC) between June and October 2006. This work included an office-based review of the geological conditions associated with the route and subsequent field investigations of specific locations identified along the pipeline alignment. The Kilometre Posts (KPs) referenced in the text and tables of this document are current as of October 22, 2009 and refer to the Revision R alignment. The study was undertaken for previous versions of the route which varied in a few locations from the current alignment. Further sampling is recommended at selected locations during detailed design and engineering; however, based on the presently available geologic data, no locations have been identified where the route revisions would result in an increase in concern with respect to ARD.

1.1 Background

Enbridge has proposed to build an oil pipeline across central British Columbia and Alberta from Bruderheim, northeast of Edmonton to Kitimat on the Pacific coast. The pipeline will consist of a 914 mm diameter (NPS 36), pipe that will transport 83,400 m3/d (525,000 bbl/d) of oil per day from Bruderheim to Kitimat, and a second 508 mm diameter (NPS 20) diameter pipe that will transport approximately 30,700 m3/d (193,000 bbl/d) of condensate in the opposite direction from Kitimat to Bruderheim. Construction of the pipelines will also require the construction of a marine terminal, tankage, pumping stations, two tunnels and related facilities and infrastructure.

Due to various constraints, the pipeline alignment is essentially restricted to its current location, though a few alternates from the current route are being investigated. Thus, in most areas, it may not be possible or practical to deviate from this alignment to avoid areas of potential ARD concern, although such route changes are not completely ruled out at this stage of the work.

1.2 Scope of Work

Primary tasks completed under this project and covered in this report include:

- Identification of known sulphide mineralization and potential rock types permissive to ARD within the proposed corridor through a geographic information system (GIS) based data analysis and literature review;

- Reconnaissance of the known sulphide mineral occurrences and sulphide-permissive rock units near the alignment; and,
- Investigation and sampling of identified locations along the corridor to assess their potential to generate acid and/or leach metals into the environment.

"Permissive" in the foregoing means that the general geological environment, known occurrences of sulphide and/or other information indicates that sulphides *might* occur in the particular rock units or geological environment. However, the permissive rocks do not necessarily contain sulphides and almost certainly do not contain sulphides over the entire range of the permissive unit or geology.

2.0 INTRODUCTION TO ACID ROCK DRAINAGE

2.1 What is Acid Rock Drainage?

Acid rock drainage (ARD) is a term used to refer to the naturally-occurring acidic runoff generated when rocks containing certain reactive minerals called sulphides (primarily pyrite, FeS_2) are exposed to air and water in a process called oxidation. The process of oxidation causes pyrite to breakdown into its chemical components, iron and sulphur, according to the following reaction:

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4SO_4 + 4H^+$$

Acidic waters formed by sulphide oxidation may break down other metal-bearing minerals and cause the release of dissolved metals, a process referred to as metal leaching (ML). In some cases, metal leaching may occur without the onset of acid rock drainage, though they usually occur together.

Acid rock drainage and metal leaching (ARD/ML) may have significant impacts on water bodies such as rivers and lakes, and on the aquatic organisms and wildlife in contact with them. As such, activities involving significant rock excavation that might trigger or enhance ARD/ML, such as mining or linear project construction, are of potential concern.

As illustrated in the above equation, three parameters must be present for acid rock drainage to occur:

1. Oxygen
2. Water
3. Sulphide minerals

Not all sulphide minerals contribute to acid rock drainage, and of the ones that do, not all of those contribute equally. Pyrite is the most common and abundant sulphide mineral. It oxidizes rapidly and is capable of generating the most acidity per unit. As such, pyrite has been identified as the primary control factor for potential ARD locations along the pipeline route. Therefore, identification of pyrite and pyrite-bearing units and their potential for ARD were a prime focus of this investigation.

2.2 Where is Acid Rock Drainage Likely to Occur?

Pyrite has been reported in rocks of all types and ages, but is found most often in sedimentary lithologies such as shales and in metamorphic rocks where it may be either a primary or a secondary mineral. Pyrite is also frequently found in hydrothermal veins and as a minor component in igneous rocks. ARD is frequently associated with mines and mineral deposits due to the presence of extremely high concentrations of sulphides (either as primary ore minerals or accessory minerals) that are exposed to weathering during mining.

Pyrite forms in several sedimentary environments including marine settings, euxinic (stagnant or anaerobic) basins, or swamps and lakes as a result of bacterial sulphate reduction. These environments require the presence of decomposable organic matter, dissolved sulphate and reactive detrital iron minerals to form pyrite in the sedimentary rocks. The amount of pyrite

precipitated from bacterial sulphate reduction is controlled by the availability of these three parameters.

Pyrite may also be present in metamorphic rocks, either as a secondary mineral formed during metamorphism, or as a relict primary mineral that is stable in almost every type of metamorphic condition (up to high grades). Additionally, hydrothermal pyrite is commonly associated with metamorphism and hydrothermal fluid flow related to intrusive rocks. This type of pyrite can occur in quartz veins, usually as part of an assemblage of sulphide and gangue minerals, or as disseminations throughout the rock mass.

The proposed pipelines cross numerous northwest-southeast oriented major geologic units (known as terranes) within British Columbia and Alberta that span a wide range of geologic environments favourable to pyrite formation (sedimentary, metamorphic and hydrothermal). In British Columbia, over 12,000 sulphide-bearing mineral occurrences have been documented (MINFILE, 2006). Rock types favourable to the presence of pyrite and sulphide mineralization are significantly less extensive in Alberta, being generally confined to the Rocky Mountains.

2.3 Quantifying Acid Rock Drainage Potential

Just as not all sulphide minerals generate equal amounts of acid, not all sulphide-bearing rocks are potentially acid generating. In some cases, the acid generated from the oxidation of sulphide minerals may be neutralized by reactions with acid-buffering minerals in the same rock. The ability of a particular rock to generate acidity is a function of the balance between acid producing minerals (sulphides) and acid consuming minerals (carbonates). Though many common rock forming minerals are capable of neutralizing acid, the most important acid neutralizers are carbonates because they react quickly and generally provide more acid neutralization per unit than other minerals. The balance between acid production and neutralization is expressed as the ratio of neutralizing potential (NP) to acid potential (AP), known as the Net Potential Ratio, or NPR. NP and AP are determined by analytical testing of rock samples that are spatially and mineralogically representative of the unit of interest.

In British Columbia, a rock is considered to be acid generating if the ratio of NP to AP is less than 1 and non-acid generating if the ratio is greater than 4. A rock with an NPR between 1 and 2 is classified as possibly acid generating, whereas rock with an NPR between 2 and 4 has a low potential for acid generation. In general, rocks with an NPR between 2 and 4 require additional tests to determine their acid generating potential, though practical experience has shown that rocks with an NPR greater than 2 are not acid generating except under unique circumstances (Price, 1997). Although developed in British Columbia, these guidelines are generally accepted throughout Canada and are gaining worldwide acceptance.

It is important to note that certain potentially deleterious elements may be liberated from the oxidation of sulphide minerals (e.g., zinc from sphalerite or arsenic from arsenopyrite) and may be present at elevated concentrations in water even after neutralization of acidic pH values occurs.

2.4 Regional Geology of the Pipeline Alignment

The proposed pipeline route crosses six broad physiographic regions (AMEC, 2009). These regions are described below from west to east, since most of the potential ARD generating terranes are in BC.

2.4.1 Coastal Mountain

The Coastal Mountain physiographic region extends from the Kitimat Terminal area at kilometre 1172.2 eastward to kilometre 1066.9. Elevations along the proposed pipeline route through the Coastal Mountains range from close to sea level at the Kitimat terminal to 1375 m in the east. Topography is generally rugged with areas of very steep high slopes, glaciers, incised canyons and flat-bottomed valleys that are infilled with glaciofluvial or alluvial sediments. The route through the highest part of the Coast Range near Mount Nimbus is proposed to include two tunnels.

Surficial materials in this region include extensive deposits of colluvium, till, and glaciomarine clays below elevations of approximately 215 m on the west side of the area. Many large U-shaped valleys have been partially infilled with glaciofluvial sediments with some areas of glaciolacustrine and glaciomarine accumulations. Colluvium in the form of scree is common below many of the steep rock slopes, which are mantled by till of variable thickness.

Bedrock geologic conditions in the Coast Mountains are complicated and include the Central Coastal Plutonic Complex which is composed of four primary groups: The Hazelton, Kamloops, Skeena, and Carmacks Groups (Journeay et al, 2000a; Gottesfeld, 1985). The Hazelton Group (including the Telkwa Formation, which is known to host volcanogenic massive sulphide, copper porphyry and copper-iron skarn type deposits) consists of shale, basalt, andesite and volcanic breccia. The Kamloops Group consists of basalt, andesite and rhyolite. The Skeena Group consists of siltstone, sandstone, conglomerate and pyritic shale units. The Carmacks Group contains basalt and andesite, while the Central Coastal Plutonic Assemblage contains a geologically complex sequence of intrusive rocks (Journeay et al, 2000a) some of which have been subjected to low-grade metamorphism and/or tectonic deformation.

2.4.2 Interior Plateau

The Interior Plateau physiographic region occupies a wide area of central and eastern BC from KP 1066.9 to KP 663.5 at elevations typically less than 1800 m. This region includes the Chilcotin Ranges, Nechako Lowlands, the northern portion of the Nechako Plateau, the southern portion of the Northern Rocky Mountain Trench, and the western flank of the MacGregor Plateau. Surficial deposits of thick glacial drift include till, drumlins, terraces, eskers, glaciolacustrine and glaciofluvial deposits (Ecological Stratification Working Group, 1996). The depth of surficial materials is variable with local areas of rock outcrops, but much of the area is overlain by thick till.

The bedrock of the Interior Plateau physiographic region is composed of three geologic terranes (Cache Creek, Stikine, and Omineca Belt; Journeay et al, 2000b, Wheeler et al, 1991) that include six significant groups (Slide Mountain, Kamloops, Gambier, Cache Creek, Nicola, and Chilcotin). The Pinchi Fault occurs within this region on a northwest/southeast trend and a distinct change in tectonic assemblage occurs across the fault (Journeay et al, 2000b; Tipper, 1971).

The Slide Mountain Group contains volcanic rocks, primarily breccia and pillow basalt. The Kamloops Group contains basalt, andesite and rhyolite (Journeay et al, 2000b). The Gambier and Cache Creek Groups include volcanic rocks with greywacke, siltstone and conglomerate. The Nicola Group is composed of volcanic rocks and volcaniclastic flows, including andesite and basalt. The Chilcotin Group is basaltic (Journeay et al, 2000b).

2.4.3 Rocky Mountains

The Rocky Mountains physiographic region in eastern British Columbia extends from KP 663.5 to KP 560.4. The regional elevations are significantly higher than in the surrounding physiographic regions, reaching approximately 1500 m along the proposed pipeline route. Till, glaciolacustrine sediment, alluvial fans, organic deposits, colluvium and exposed bedrock ridges are dominant along the pipeline route (Vold et al, 1977).

The Rocky Mountains contain a complex bedrock assemblage that includes seven tectonic assemblages (Wheeler et al, 1991). Widespread folding and thrust faulting has produced northwest-southeast ridges. Bedrock along the route includes the Windermere, Gog, Rocky Mountain, Kootenay, Besa River, Smoky, and Rundle Groups (Journeay et al, 2000b). The Windermere Group contains sandstone, siltstone and shale. The Gog Group contains conglomeritic sediments, mafic flows and quartzite (Journeay et al, 2000b). The Rocky Mountain Group contains dolomite, limestone, sandstone, and shale. The Kootenay Group contains sandstone and mudstone. The Besa River Group includes shale and pyritic mudstone, while the Smoky Group has generally coarser-grained sediments that typically do not contain sulphides. The Rundle Group is composed of continental shelf carbonates and shale (Journeay et al, 2000b).

2.4.4 Alberta Plateau

The Alberta Plateau extends from KP 560.4 to KP 516.8 and has gently rolling topography with some steep ridges and elevations between 1070 and 1225 m. Surficial materials include till, glaciolacustrine and glaciofluvial sediment, colluvial deposits and organic material (Vold et al, 1977).

While the thrust-faulted bedrock underlying the Alberta Plateau physiographic region has little exposure, it primarily consists of the Spray River, Brazeau, and Smoky Assemblages or Groups. The Spray River Assemblage contains siltstone, sandstone, and limestone. The Smoky Group is made up of the Muskiki Formation pyritic shale, in addition to marine siltstone and sandstone. The Brazeau Group consists of sandstone, conglomerate and shale (Journeay et al, 2000b).

2.4.5 Southern Alberta Uplands

The Southern Alberta Uplands physiographic region extends from KP 516.8 to KP 165.8, and has undulating to hummocky topography with elevations along the proposed pipeline route from 800 to 975 m.

Surficial deposits typically obscure bedrock with thicknesses between 3 and 20 m and consist of organic, lacustrine, fluvial and aeolian deposits (Twardy and Corns, 1980; Knapik and Lindsay, 1983).

The Southern Alberta Uplands are underlain by sedimentary bedrock of three major flat-lying formations with some regional folding and thrust-faulting parallel to the Rocky Mountain thrust faults: the Upper Paskapoo, Wapiti and Scollard Formations (Journeay et al, 2000c; Knapik and Lindsay, 1983), all of which contain a variety of conglomerate, siltstone, shale, and coal.

2.4.6 Eastern Alberta Plains

The Eastern Alberta Plains physiographic region extends from KP 165.8 to KP 0 with elevations along the proposed pipeline route from 800 m to approximately 700 m toward the east end. The topography is dominated by undulating terrain underlain by fine-grained glaciolacustrine deposits averaging 20 m thick (silts and clays with some interbedded sand), and undulating to hummocky glacial till. Localized coarse glaciofluvial deposits (sand and gravel containing varying contents of pebbles and boulders) also occur, as do glaciolacustrine deposits.

The Eastern Alberta Plains physiographic region is underlain by the flat-lying Horseshoe Canyon and Scollard Formations (Journeay et al, 2000c). The Horseshoe Canyon Formation occupies the majority of this physiographic region and includes sandstone, mudstone and shale. Localized ironstone concretions, scattered coal seams and bentonite seams may also be present (Shetson, 1990). The underlying Scollard Formation contains sandstone and mudstone rock types, with frequent interbeds of shale and coal, and also contains bentonite and smectite clays (Journeay et al, 2000c).

2.5 Summary of Key ARD Background Points

- Acid rock drainage (ARD) is caused by the oxidation of sulphides, primarily pyrite. The presence or absence of other minerals that can neutralize acid determines the ability of a particular rock to produce ARD.

- Sulphides occur in many different rock types. Although frequently associated with metal and coal mines, sulphides can occur in appreciable concentrations in a wide range of geological and physiographic environments.

- Excavation of ARD prone rock will result in an increase in its surface area and an increase in the rate of weathering, resulting in the potential generation of ARD. Potentially, ARD conditions could result on both excavated rock surfaces (rock cut slopes and/or along the pipeline trenches) and on excavated rock materials.

- As a result of the geologic conditions found in Western Canada, the occurrence of sulphides is restricted primarily to British Columbia, although sulphides do occur within the Rocky Mountains area of Alberta. ARD is not expected to be an issue within most of Alberta.

- Thick and extensive accumulations of glacial till, glacial sediments and alluvial sediments are found throughout the valleys and plateau areas of British Columbia and Alberta. Bedrock may not have to be excavated in these areas, resulting in a significantly decreased potential for ARD to occur.

3.0 IDENTIFICATION OF POTENTIAL ARD PRONE AREAS

3.1 ARD/ML (Sulphide) Occurrence Models

As discussed in the previous section, the proposed pipeline route extends for approximately 1172 kilometres across a complex assemblage of geological units and regions with the potential to host sulphide mineralization or pyritic lithologies. These factors make it difficult to identify the presence of all sulphide mineralization or pyritic lithologies along the entire route. However, through the use of extensive National and Provincial geological databases and accepted geological models of sulphide mineralization, it is possible to identify some areas where ARD may occur.

In order to provide an initial assessment of potential ARD prone areas, the geology underlying the pipeline route was evaluated for its potential to contain sulphides. GIS was used to integrate the data and interrogate datasets using three different models of sulphide occurrence. Those models are:

1. Known sulphide mineralization (such as the copper-silver Equity Silver mine);
2. Known pyrite-bearing lithologies (such as the Muskiki shale), and;
3. Geology permissive for sulphide mineralization or pyritic lithologies.

These three models vary in their degree of certainty regarding the presence of sulphide minerals. The goal of this office-based assessment was to identify known and potential ARD sources along the route to be candidates for field checking. Details of each model are described below.

3.1.1 Model 1 - Known sulphide mineralization

In this model, the locations of known sulphide minerals are the targets. A British Columbia provincial database (MINFILE) containing information on reported sulphide mineralization was queried and the results mapped to identify locations of sulphide mineralization near the alignment. The nature of sulphide mineralization tends to be highly localized and, at the provincial scale, is described as a ‘point source’. The spatial relation of mineralization to the pipeline alignment is a key factor, with occurrences in proximity to the alignment (i.e., within 3 km), or in the same drainage basin considered for the purposes of this work to have a higher likelihood of ARD/ML impacts. Additionally, the likelihood of encountering pyrite or sulphides related to known mineralization decreases significantly with increasing distance from the pipelines.

Coal deposits are considered to fall under this model due to their propensity to leach soluble metals such as selenium (ARD conditions not necessarily required), though specific coal deposits may not have metal leaching issues.

3.1.2 Model 2 – Known pyrite-bearing lithologies

Under this model, rock units that cross the pipelines and that are reported to have pyritic units were identified[1]. This model captures mostly sedimentary rock types, such as black shales, and their metamorphic equivalents.

As the geologic fabric of BC trends northwest-southeast, any pyrite-bearing rock units crossed by the east-west pipeline alignment will highlight a lateral extent of pipeline corridor as having a potential for ARD. This 'linear' model results in a larger area of investigation than that seen in the 'point source' Model 1 and requires detailed investigation for the presence of outcrop along a wider section of the pipeline route.

3.1.3 Model 3 – Permissive geology for sulphide mineralization

This model is an amalgamation of the two previous models. General rock types (not to be confused with the specific lithologic units in Model 2) that are known to host pyrite or other metal sulphides are termed 'permissive', and as such, investigation of these lithologies is required where they are near the alignment.

This model captures all rock units considered capable of hosting sulphide mineralization or pyrite bearing lithologies, but that have no documented occurrences of sulphides near the intersection with the alignment. For example, black shales are known to contain pyrite; therefore, any black shale units crossing the pipeline corridor would be considered permissive for the presence of pyrite. Or, an entire rock unit that contains copper-zinc mineralization at a site not in proximity (i.e., greater than 3 km away) to the alignment is considered to be permissive to the presence of sulphide mineralization.

3.2 Data and Model Processing

Several sources of information were used to develop a target list based on the above models. These sources are summarized below.

3.2.1 Detailed Geology

The British Columbia Geological Survey (BCGS) and the Geological Survey of Canada (GSC) have an extensive on-line collection of digital and paper maps. Generally, mapping is at 1:250,000 scale, but also incorporates larger scale mapping in several areas along the pipeline route, as well as more detailed maps for specific areas. Large scale geological maps were scanned and georeferenced for verification. Table 3.1 summarizes maps available along the pipeline route at a larger scale than the background 1:250,000.

[1] Pyrite can occur as a common accessory mineral in some rock types, but its presence may not result in the classification of a mineral occurrence.

Table 3.1: BC Geological Survey Maps

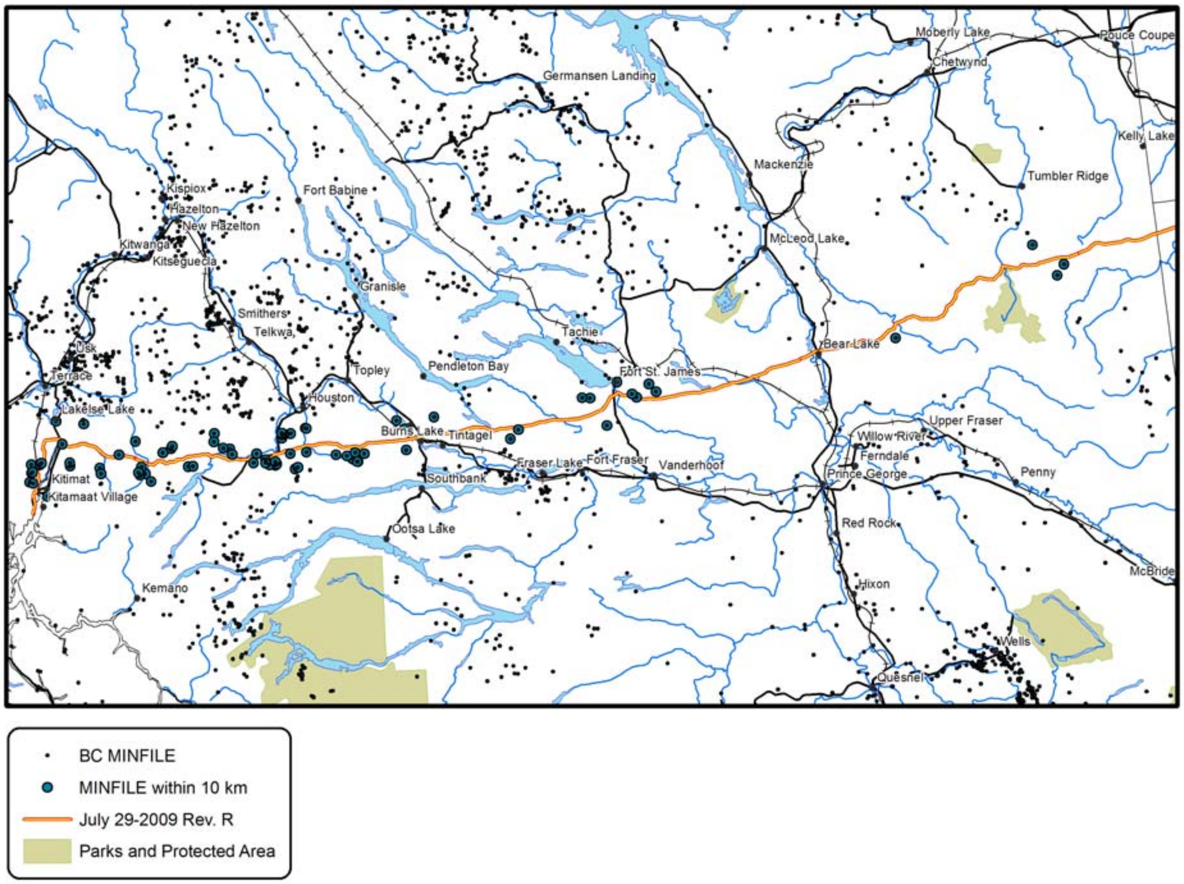
Title	NTS Map	Scale	Authors
Geology of the Lamprey Creek Area	093L/03	1:50,000	Desjardins and Arksey
Geology of North-Central Quesnellia Tezzeron Lake to Discovery Creek Central British Columbia	93K; 93N	1:100,000	Nelson
Bedrock Geology of Kinuseo Falls Area, Northeast British Columbia	093I/14-15	1:50,000	Kilby and Johnston
Preliminary Geologic map of Terrace (NTS 103I East Half) map Area, British Columbia	103I/01; 103I/02; 103I/07; 103I/08; 103I/09; 103I/10; 103I/15; 103I/16	1:125,000	Woodsworth, Hill, Van Der Heyden
Geology of Smithers map-area, British Columbia	093L	1:125,000 1:250,000	Richards, Tipper
Bedrock Geology, Burns Lake, British Columbia	093K/03; 093K/04; 093K/05; 093K/06	1:100,000	Struik, Fallas, Hrudey, Whalen
Geology of Monkman Pass map-area, northeastern British Columbia	093I	1:25,000	Stott, Taylor

3.2.2 MINFILE Database

The British Columbia Ministry of Energy, Mines and Petroleum Resources (BC MEMPR) maintains an online database of all metal and industrial mineral occurrences in BC known as MINFILE. The MINFILE database contains geologic, location and economic information on over 12,250 metallic, industrial mineral and coal deposits and occurrences in B.C. Information from this database was plotted with GIS software to identify where known sulphide mineralization and coal occur, and annotated to indicate the positional accuracy of recorded locations. Subsets of the database were then created at 10 km and 3 km buffers. The 10 km buffer is assumed to be the maximum extent of possible pyrite alteration envelopes. The 3 km subset highlights known mineral occurrences within 1.5 km of the Revision R pipeline route (± 1.5 km for positional accuracy). MINFILE occurrences within 3 km are expected to have the greatest potential for ARD/ML impacts due to proximity to the pipeline alignment.

All occurrences were given equal weight regardless of status from small showings to current or past producing mines. Figure 3.1 shows BC MINFILE occurrences within 10 kilometres of the pipeline corridor.

Figure 3.1: British Columbia MINFILE Occurrences

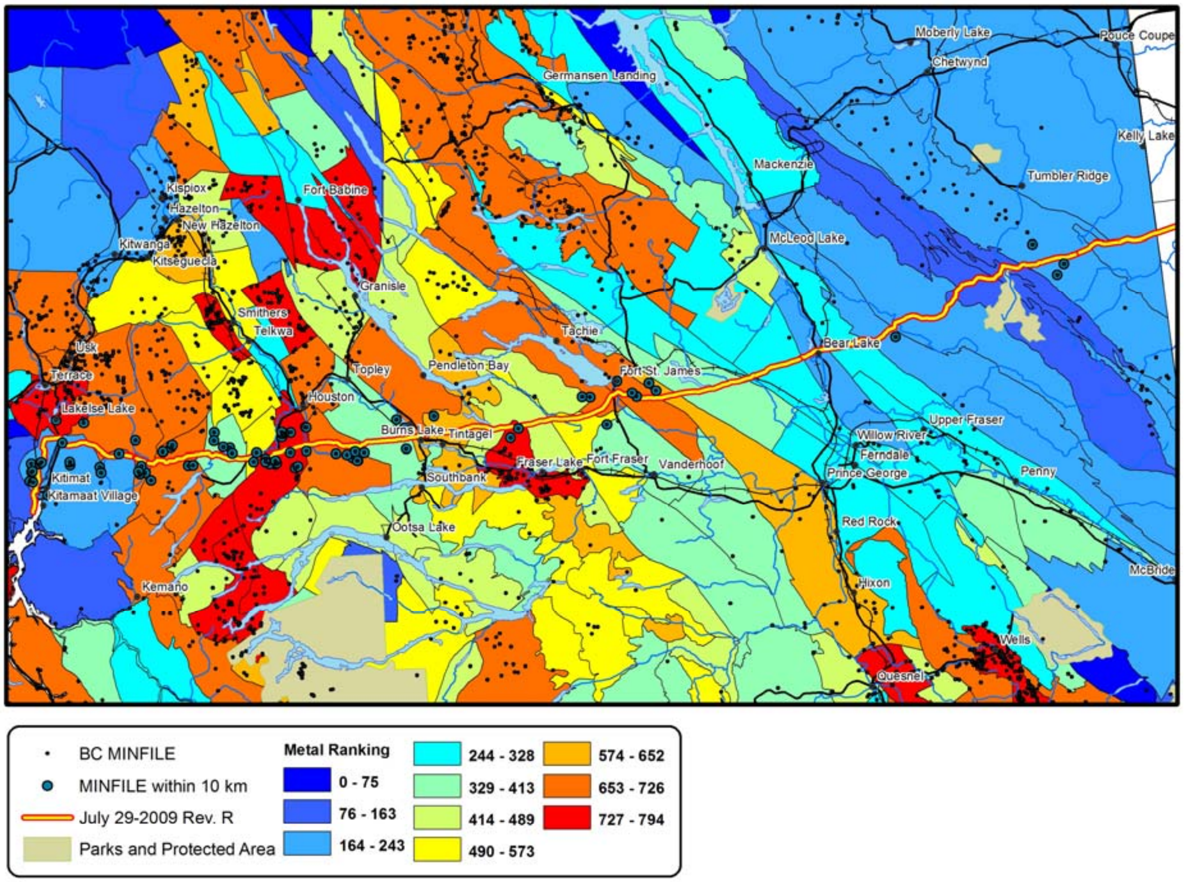


3.2.3 Mineral Potential Mapping

The mineral potential project was a multi-year study completed by the BC Geological Survey and summarized in *The British Columbia Mineral Potential Project, 1992-1997, Methodology and Results* (Kilby, 2004). The project is a quantitative assessment of mineral potential of both metals and industrial minerals for 795 tracts in the province of BC. The assessment is based on MINFILE, assessment reports, regional geochemical surveys, geophysics, deposit models, and geology. A panel of experts estimated the number and likelihood of undiscovered deposits for each deposit type on each tract. Based on this work, a ranking of the relative potential of each tract in the province was determined.

The metal potential ranking, as an indication of the potential for sulphide mineralization, was plotted using percentiles generated from the province-wide dataset to provide a quantitative overview of land tracts permissive to sulphide mineralization (Figure 3.2).

Figure 3.2: Mineral Deposits Potential Mapping and MINFILE Occurrences



3.2.4 Regional Geochemical Surveys

The BC MEMPR has been involved in reconnaissance-scale stream sediment and water surveys since 1976. As part of Canada's National Geochemical Reconnaissance (NGR) program, the regional geochemical survey (RGS) program continues to maintain sample collection, preparation and analytical standards established by the Geological Survey of Canada. To date, over 45,000 stream sediment and water samples have been collected from approximately 70 percent of the province. The resulting field and multi-element analytical data are compiled into B.C.'s largest and most comprehensive stream sediment and water geochemical database (http://www.em.gov.bc.ca).

RGS data within 20 km of the pipeline alignment was examined for acidic pH values or elevated metals concentrations in streams that would indicate ARD/ML. The results are shown in Table 3.2.

Table 3.2: Regional Geochemical Samples with Acidic pH

Sample No. - Mapsheet	pH
861371 - 93J08	3.7
853224 - 93L08	4.4
851749 - 93J07	4.0
853096 - 93L09	5.5

3.2.5 GIS

GIS software was used to integrate the above data into a cohesive dataset that allowed rapid assessment of factors that may contribute to ARD. The benefit of using GIS is the ability to quickly spatially relate and query factors indicating ARD (acid pH in RGS, known pyritic lithologies, sulphide mineralization) to highlight permissive geology. The field program was based on the GIS modelling results.

3.3 Identification of Potential ARD Sites

Based on the three sulphide occurrence models, a target list for potential ARD locations was established for field verification and sampling. These targets are based on an amalgamation of all of the above sources of information.

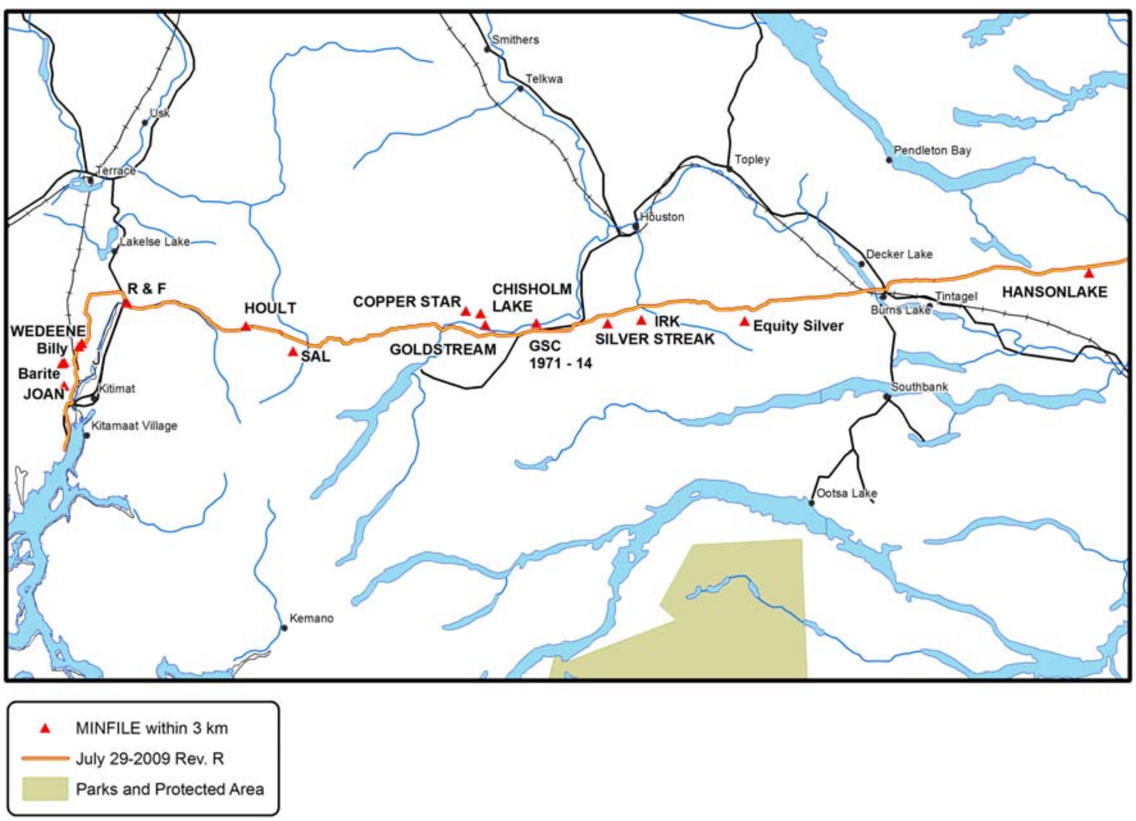
3.3.1 Model 1

The ‘point sources’ of potential ARD as determined by MINFILE occurrences are summarized in Table 3.3 and illustrated in Figure 3.3. MINFILE occurrences tend to be concentrated in the western-most quarter of the pipeline route in the Coast Mountain Ranges.

Table 3.3: MINFILE Occurrences within 3 km of Rev R Alignment

Name	Lithology Commodity
Joan	Cu skarn
Barite	Volcanogenic barium
Billy	Au pyrrhotite veins
J	Massive sulphide Cu-Pb-Zn
Wedeene	Fe skarn
R&F	Cu
Hoult	Porphyry Mo
Sal	Volcanic redbed Cu
Copper Star	Porphyry Cu +/- Mo +/- Au
Chisholm Lake	Bituminous coal
Goldstream	Bituminous coal
GSC 1971-14	Volcanic redbed Cu
Silver Streak	Ag
Irk	Ag-Pb-Zn +/- Au veins
Equity Silver	Subvolcanic Cu-Ag-Au
Hanson Lake	Porphyry Cu +/- Mo +/- Au

Figure 3.3: MINFILE Occurrences within 3 km of Pipeline Alignment



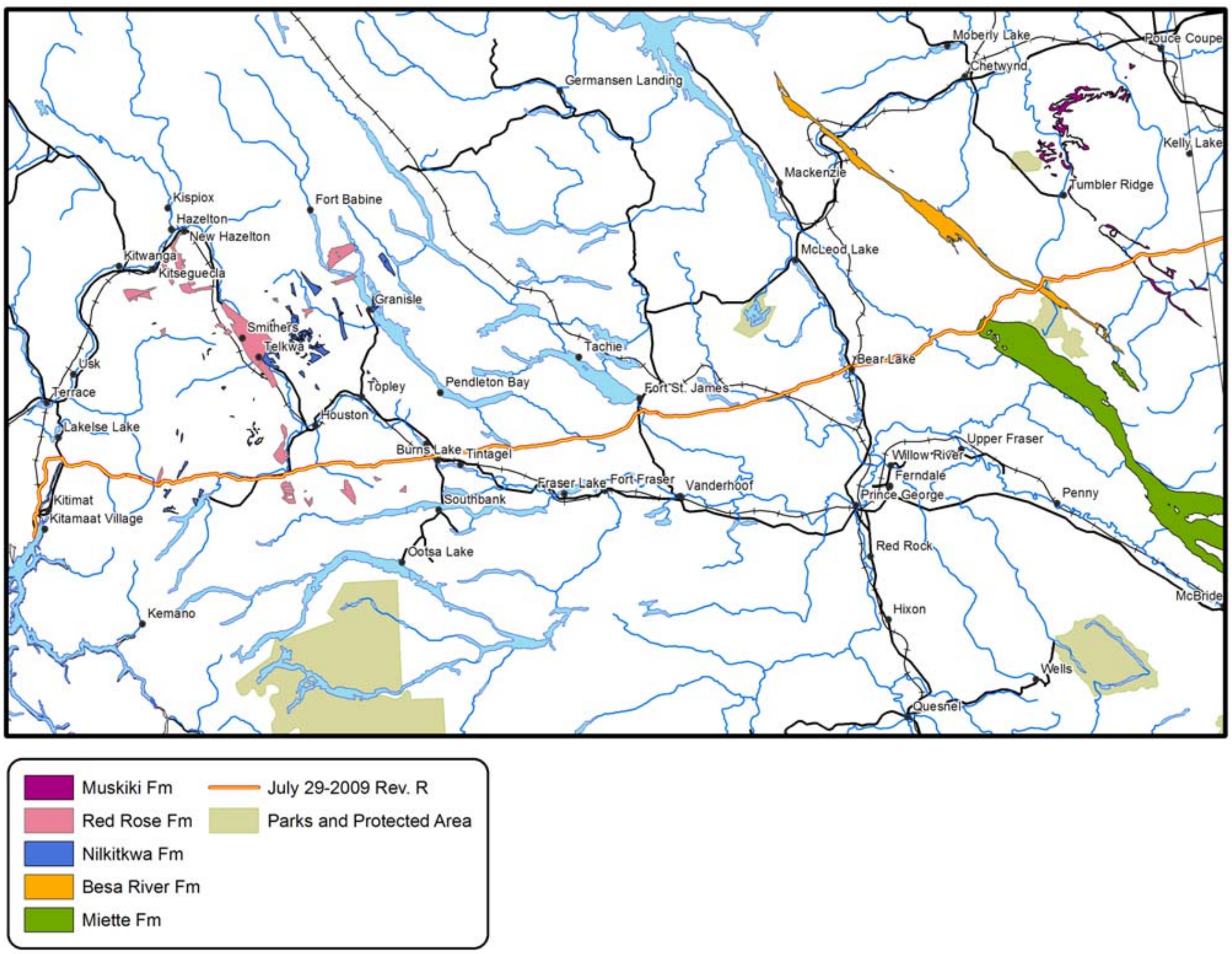
3.3.2 Model 2

A list of pyrite-bearing rock units as determined from geologic mapping, mineral occurrences, mineral potential tracts and regional geochemical surveys is summarized in Table 3.4 and shown in Figure 3.4.

Table 3.4: Geologic Units with Known Pyrite-Bearing Lithologies

Group Name	Formation Name
Hazelton Group	Nilkitkwa Fm
Wabamun Group	Besa River Fm
Smoky Group	Muskiki Fm
Skeena Group	Red Rose Fm
Miette Group	Miette Fm

Figure 3.4: Pyrite Bearing Rock Units



3.3.3 Model 3

General rock types as determined from a combination from the above two models are summarized in Table 3.5. Specific lithologies that were prioritized are fine-grained black sediment and coal. This model includes lithologic units if the regional geological survey sample returned an acidic pH value.

Table 3.5: Permissive Geological Units

Group	Formation	Lithology/Commodity/pH
Endako Batholith		Coal, Cu, Cu-Mo
Fort St. John Gp		Coal
Hazelton Gp	Telkwa Fm	Cu, Pb, Zn, Au, Mo
Kasalka Gp		Ag (+ Equity Silver mine)
Minnes Gp		Coal
Nechako Plateau Gp		Cu, Au
Poison Pluton		Cu, Fe
Takla Gp		Hg
Unnamed intrusive		Mo, Cu, Ag
Coast Plutonic		Cu
Hazelton Gp	Nilkitkwa Fm	marine shale
Unnamed shale		RGS pH 4.4
Endako Gp	Buck Ck Fm	RGS pH 3.7
Takla Gp		RGS pH 4.0
Misinchinka Gp		RGS pH 5.5

3.4 Identification of Potential ARD Areas

Based on the target list several areas permissive to ARD have been identified. These areas are concentrated in the west portion of the alignment in the Coast Ranges where the majority of MINFILE occurrences are located and in eastern British Columbia where the pyritic lithologic units outlined in Model 3 occur. The geologic units that did not intersect the alignment and RGS sample data were excluded from the process of defining potential ARD areas. RGS samples were excluded since the sample results would be extremely difficult to follow-up during field work as each sample represents an approximately 30 km^2 drainage basin, and are between 2.5 and 19 km from the alignment.

Table 3.6 summarizes potential ARD areas based on the three data model types:

Table 3.6: GIS Based ARD Targets

Model	Name	Lithology Commodity	Nearest KP (Rev R)
1	Hanson Lake	Porphyry Cu +/- Mo +/- Au	877
1	Equity Silver	Subvolcanic Cu-Ag-Au	960
1	Silver Streak	Ag	995
1	Irk	Ag-Pb-Zn +/- Au veins	987
1	Copper Star	Porphyry Cu +/- Mo +/- Au	1032
1	Chisholm Lake	Bituminous coal	1030
1	Goldstream	Bituminous coal	1026
1	GSC 1971-14	Volcanic redbed Cu	1014
1	Sal	Volcanic redbed Cu	1075
1	Hoult	Porphyry Mo	1089
1	Wedeene	Fe skarn	1144
1	J	Massive sulphide Cu-Pb-Zn	1145
1	Joan	Cu skarn	1156
1	Billy	Au pyrrhotite veins	1149
1	Barite	Volcanogenic barium	1149
1	R&F	Cu	1121
2	Hazelton Gp Nilkitkwa Fm		1051-1063
2	Wabamun Group Besa River Fm		602-606
2	Smoky Group Muskiki Fm		551.5-552.5
2	Skeena Group Red Rose Fm		1070-1072
2	Miette Group Miette Fm		638-648
3	Endako Batholith	Coal, Cu, Cu-Mo	841-944
3	Fort St. John Gp	Coal	654.5-566 and 568-569.5
3	Hazelton Gp Telkwa Fm	Cu, Pb, Zn, Au, Mo	sections between 993-1162
3	Kasalka Gp	Ag (+ Equity Silver mine)	992-994 and 1004-1111
3	Minnes Gp	Coal	570-580 and 581-588
3	Nechako Plateau Gp	Cu, Au	873.5-877.5 and 934-944
3	Poison Pluton	Cu, Fe	1120-1147
3	Takla Gp	Hg	790-799.5
3	Unnamed intrusive	Mo, Cu, Ag	1083-1095 and 1106-1120
3	Coast Plutonic	Cu	1073-1079
3	Hazelton Gp Nilkitkwa Fm	marine shale	1051-1063

4.0 FIELD PROGRAM

4.1 General Approach

Field work was split into two separate programs; a reconnaissance program and a site investigation program. During the reconnaissance program, the preliminary route from Kitimat to the Rocky Mountain foothills in Alberta was flown to assess the presence of outcrop and visual indications of ARD. Efforts were focussed on areas previously identified as potential ARD targets, however all rock outcrops identified from the air, particularly those showing evidence of sulphide oxidation, were checked along the route.

During the site investigation program, specific pre-selected target areas were inspected. Site access was primarily by helicopter; road access by truck was used wherever practicable. During vehicle-based work, any outcrop encountered near or on the alignment was also examined where feasible.

4.2 Geological Investigation and Sample Collection

The approach to each site assessment was consistent regardless of whether the site was an opportunistic location, or a location with known sulphide mineralization or pyritic lithology. The priority was to examine the geology as closely as possible to the alignment, although the nearest outcrop could be over a kilometre away. Although numerous roads cross the proposed pipeline route, most of the actual pipeline alignment, particularly within areas of interest with respect to ARD, is in heavily forested and mountainous areas that severely restrict helicopter and vehicle access. Visual assessment of the mineralogy, structure and evidence of ARD was carried out at each outcrop. Indications of potential ARD include sulphide minerals, sulphide weathering products, or iron-stained areas. Most sulphide minerals weather to red, yellow or orange secondary iron minerals, such as hematite and limonite. White, effervescent sulphate precipitates from sulphide oxidation are generally very soluble, but can sometimes be seen on rapidly oxidizing sulphides.

The 2006 sampling strategy involved investigating outcrops along the proposed corridor. The majority of samples were collected from the target locations listed above and through opportunistic sampling of outcrop near the pipelines and between targets. Where outcrop was not present due to overburden cover, but the underlying geological unit was thought to be permissive to ARD, the area of investigation was expanded until outcrop was identified, usually along nearby ridges or topographically high areas. In areas where sites were accessed via logging roads, the alignment corridor was crossed as often as possible where logging roads would permit. Outcrop within 1 km of the alignment encountered en route to targets accessed by vehicle were investigated and sampled if lithologies contained visible sulphides or obvious neutralization capacity.

At each outcrop site a 1 kg sample of each distinct lithology was taken. Care was taken to select samples that appeared to be representative of the entire outcrop and to avoid surficial weathering or alteration that might not be representative of the overall rock mass chemistry. Where sulphides were present, samples were collected to best represent the bulk composition of the observed outcrop.

Table 4.1 summarizes the coordinates of samples collected:

Table 4.1: ARD Samples Collected During August 2006 (NAD 83)

Sample ID	Zone	Easting	Northing	Sample ID	Zone	Easting	Northing
06-Alcan-001	9	519400	5984981	06-Foxy-001	9	682442	6012911
06-Alcan-002	9	518798	5986740	06-Hanson-001	10	368343	6015219
06-Term-001	9	518735	5977796	06-Hanson-002	10	368343	6015219
06-Term-002	9	518735	5977796	06-Hanson-003	10	367475	6014708
06-Term-003	9	518735	5977796	06-HOE-001	9	556803	6005780
06-Besa-001	10	613123	6069177	06-HOE-002	9	556803	6005780
06-Besa-002	10	613276	6069106	06-Hoult-001	9	561092	6006993
06-Besa-003	10	611345	6068924	06-Hoult-002	9	561161	6006636
06-Besa-004	10	611237	6069070	06-Hoult-003	9	561061	6006629
06-Billy-001	9	518422	5998136	06-Hoult-004	9	561711	6006621
06-Bulk-001	9	654723	6011610	06-J-001	9	522008	6002151
06-CloreR-001	9	573428	6003320	06-J-002	9	522008	6002151
06-CloreR-002	9	572958	6003477	06-J-003	9	522081	6002176
06-Rose-001	9	576001	6000358	06-Klo-001	9	666293	6012250
06-Rose-002	9	576009	6000433	06-Miette-001	10	582923	6051099
06-Rose-005	9	578299	6003724	06-Miette-002	10	582923	6051099
06-Rose-03	9	576323	6002087	06-Miette-003	10	582249	6051929
06-Rose-04	9	576147	6001370	06-Miette-004	10	582325	6052004
06-INT-001	9	577487	6002003	06-Miss-007	10	584287	6053515
06-INT-002	9	577545	6002150	06-Miss-001	10	568738	6052401
06-EM-001	9	678776	6010126	06-Miss-002	10	568322	6052500
06-EM-002	9	679489	6010865	06-Miss-003	10	567097	6053045
06-EM-003	9	679996	6010705	06-Miss-004	10	567336	6053061
06-EM-004	9	680483	6010513	06-Miss-005	10	576327	6050971
06-EM-005	9	680483	6010513	06-Miss-006	10	577320	6050893
06-EM-006	9	680483	6010513	06-Mor-001	9	633507	6010506
06-EM-007	9	679553	6010859	06-MuskN-001	10	656199	6081737
06-EMW-001	9	671945	6011156	06-MuskN-002	10	656423	6081845
06-EMW-002	9	671945	6011156	06-Streak-06	9	646321	6007516
06-Endak-001	9	685117	6014933	06-Telkwa-001	9	624866	6007877
06-Endak-002	9	685382	6013908	06-Telkwa-002	9	613767	6008886

5.0 ANALYTICAL AND INTERPRETIVE METHODOLOGY

All samples were submitted to Vizon Scitec (formerly BC Research) for acid base accounting, trace element analysis and total metal analysis by X-ray fluorescence (XRF). The analytical methods and acid generation classification are summarized below.

Data interpretation was based on industry standard approaches and methods of data interpretation used in the mining industry for the assessment and classification of acid generation in mine materials.

5.1 Whole Rock Analysis

Whole rock analysis (WRA) by X-ray fluorescence (XRF) determines the major element composition of a rock in terms of weight percent oxide via lithium metaborate fusion. WRA is a useful tool for determining rock type, and when used in conjunction with trace metals analysis, WRA can help to highlight concentrations of elevated metals.

5.2 Total Metals

Total and trace metals are determined by inductively coupled plasma mass spectrometry (ICP) analysis following a strong acid *aqua regia* digestion. Total metal analysis can be compared to average crustal abundances of these elements for a specific rock type in order to highlight metal concentrations that may possibly be of concern during in situ weathering of the rock. In order to determine elemental enrichment, the analytical results for CCME (Canadian Council of Ministers of the Environment) regulated elements (As, Cd, Cr, Cu, Fe, Pb, Hg, Mo, Ni, Se, Ag, Tl and Zn) were compared to five times the average concentration values for specific rocks types (Price, 1997). As such, this screening criteria threshold limit varies with rock type. Rock classification of samples was based on field observations and comparison of whole rock XRF data to published average compositions for various rock types (Price, 1997). The rocks were classified as either ultrabasic (mafic composition, intrusive and volcanic rocks), basaltic (intermediate composition intrusive and volcanic rocks), granitic (felsic composition intrusive and volcanic rocks), shale (black shale), sandstone (orthoquartzite, arkose) or deep ocean clay sediment (grey phyllite). While the list of published rock types does not exactly match the rock types seen in the field, it provides a base for comparative purposes.

5.3 Acid Base Accounting

Acid base accounting (ABA) by modified Sobek method via total sulphur analysis is a technique for determining the potential of a rock to generate acid when exposed to weathering.

The ability of a rock to generate acid is a function of the balance between the potentially acid producing (sulphide) minerals and the potentially acid consuming minerals. As such, ABA analysis is based on the neutralization potential (NP) of a rock assuming all neutralizing minerals react like calcium carbonate and the acid potential (AP) of a rock assuming all sulphide

minerals react like pyrite. The guidelines for ARD potential based on Price (1997) are listed in Table 5.1, where NPR (Net Potential Ratio) is the ratio of NP to AP:

Table 5.1: ABA Screening Criteria (Price, 1997)

Potential for ARD	Initial Screening Criteria	Comments
Likely	NPR <1	Likely acid generating, unless sulphide minerals are non-reactive
Possible (uncertain)	1<NPR<2	Possibly acid generating if NP is insufficiently reactive or is depleted at a rate faster than sulphides
Low	2<NPR<4	Not potentially acid generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP
None	NPR >4	

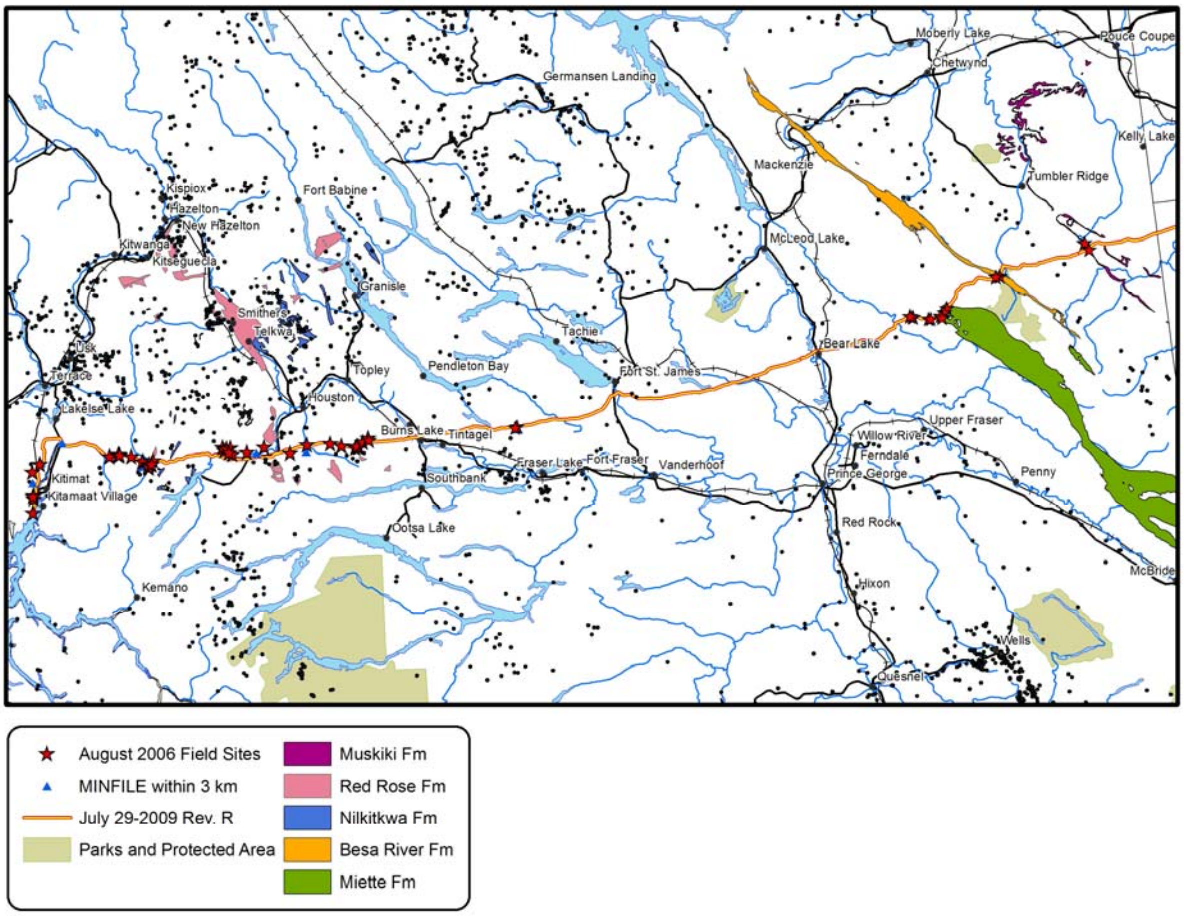
As per the screening criteria of BC ARD Guidelines, materials with a sulphide-sulphur content less than 0.3% and a paste pH of greater than 5.5 require no further ARD testing unless there are other metal leaching concerns.

Negative NP values indicate an absence of neutralization potential and the number should not be used to generate the NPR. Instead, the net neutralization potential (NNP = NP - AP) is utilized to determine the PAG nature of the sample. The first 20 kg $CaCO_3$/t of a sample is considered to be 'unavailable'. Any sample with an NNP less than 20 is considered to have no capacity for acid neutralization.

6.0 FIELD INVESTIGATIONS AND ANALYTICAL RESULTS

The visual assessment of the pipeline alignment confirmed expectations that indicators of ARD potential are minimal outside of the target list, either due to the absence of outcrop or the lack of sulphides within existing outcrops. During mobilization to target sites (via truck or helicopter) all outcrops encountered near the alignment were visually assessed for ARD potential. In several cases, samples were collected at these opportunistic sites, regardless of visible sulphide content. Figure 6.1 presents the sites visited during the reconnaissance and site investigation programs. ABA results are presented in Appendix A for each site.

Figure 6.1: Locations of Site Investigations



A summary of each site is presented below. Detailed site and sample descriptions, and photographs are presented in Appendix B.

6.1 Kitimat Terminal Area

Table 6.1 contains a summary of samples collected from the Kitimat Terminal area.

Table 6.1: Kitimat Terminal Area Samples

Sample	Rock Type	Nearest KP
06-Term-001	mafic intrusive	210 m southeast of KP 1172
06-Term-002	felsic dyke intrusive	210 m southeast of KP 1172
06-Term-003	rusty weathering pyrite-bearing vein	520 m west of KP 1172

The Kitimat Terminal Area site has a large fresh road cut exposure of generally unweathered rock along a logging road. The outcrop is approximately 100 m long and 15 m high with an average pyrite content of <1% (visual estimate). Localized clots of 1 to 4 cm euhedral pyrite crystals were observed in mafic, rusty-weathering veins associated with quartz veining that is cross cut by younger felsic dykes. The felsic dykes contain only trace amounts of pyrite. There is minor pervasive epidote-calcite alteration of the intrusive rocks. One sample of each of the mafic (06-Term-001) and felsic (06-Term-002) phases was collected to generally characterize the outcrop. A third sample of the quartz-pyrite veining was collected to characterize the potentially acid generating (PAG) rock (06-Term-003). The mafic phase comprises approximately 60% of the total volume of the observed outcrop, while the vein material containing pyrite comprises <1%.

Paste pH values ranged from a low of 3.9 for the pyritic sample to 9.0 and 9.5 for the mafic and felsic rocks respectively. Sulphide sulphur content ranged from a high of 3.2% for the pyritic sample, to 0.5% in the mafic rock and was below detection limits in the felsic rock. NP ranged from 1.4 to 11.6, with corresponding NPR values between 0.0 and 12.9. Molybdenum exceeded the metals screening threshold. Copper also exceeded the screening threshold in the mafic rock and pyritic vein samples of 84.9 mg/kg and 426.2 mg/kg, respectively.

The construction of the terminal area will result in the disturbance of a large volume of rock. Based on the grab samples collected (which concentrated on areas of visible pyrite), some of the mafic volcanic rock and the pyrite bearing veins are classified as potentially acid generating (PAG). The felsic dykes are considered to be not acid generating (NAG).

6.2 West Side of Lower Kitimat Valley

Table 6.2 contains a summary of samples collected from the west side of lower Kitimat Valley.

Table 6.2: West Side of Lower Kitimat Valley Samples

Sample	Rock Type	Nearest KP
06-Alcan-001	intrusive (granodiorite)	230 m northeast of KP 1165
06-Alcan-002	volcanic	480 m northeast of KP 1162
06-Powerline	no sample collected	320 m southeast of KP 1163

Three separate outcrop sites were visited along a 3 km stretch of the pipeline alignment, west of the Alcan Plant site in the general area of the proposed pipeline route. At the southernmost outcrop (06-Alcan-001), the Poison Pluton is exposed adjacent to the road. It has an average visible sulphide content of <1%, pervasive chlorite alteration and some quartz and/or calcite veining. Approximately 1 km north of the southernmost outcrop, vegetation partially obscures the several metre high observed fault contact of the Poison Pluton with Telkwa Formation volcanic rocks. A sample of the volcanic rock near the contact with the pluton was collected (06-Alcan-002). Overall sulphide content at this site was <1% and chlorite alteration is pervasive. The westernmost outcrop is located on a ridge directly between the two previous sites, and at much higher elevation. At this site, the Poison Pluton outcrops and is chloritically altered and weakly magnetic due to the presence of euhedral magnetite crystals (06-Powerline). This outcrop contains no visible sulphides.

The Poison Pluton sample had a paste pH of 9.3, a sulphide sulphur content of 0.2%, an NP of 14.5 and a corresponding NPR of 2.6. The sample contained 6.1 mg/kg molybdenum, which exceeds the CCME screening threshold. The Telkwa Formation volcanic rock sample at this site had paste pH of 9.4, a sulphide sulphur content of 0.2%, an NP of 11.8 and an NPR of 2.5.

Both the intrusive and the volcanic rocks are classified as NAG.

6.3 Billy (Minfile# 103I 218)

Table 6.3 contains a summary of samples collected from the Billy (Minfile # 103I 218) area.

Table 6.3: Billy Minfile Samples

Sample	Rock Type	Nearest KP
06-Billy-001	altered volcanic	2.3 km west of KP 1149

The Billy gold and base metal showing is exposed in a steep outcrop of rock along a logging road covered in second growth vegetation. The site is approximately 2 km west and 700 m above the alignment on a topographic high. The outcrop contains Telkwa Formation volcanic rocks with quartz veinlets and minor amounts of pyrite. Local zones of intense pervasive silicification are accompanied by abundant, very fine-grained, disseminated pyrite. These zones

are rusty weathering, but appear to be limited to a few square meters in extent. Chlorite-epidote alteration is both pervasive and veinlet controlled. The general lack of outcrop in the area hinders a broader delineation of the potentially pyritic alteration zones. Field observations suggest that the extent of pyrite alteration appears quite limited, however, the potential remains that similar pyrite alteration may be encountered elsewhere in the Telkwa Formation.

The paste pH of the Telkwa Formation at this site was 9.0, sulphide sulphur content was 0.4%, NP is 6.3 and NPR is 0.5, indicating that it is PAG. No elements exceed the screening criteria.

6.4 J (Minfile# 103I 221)

Table 6.4 contains a summary of samples collected from the J (Minfile# 103I 221) area.

Table 6.4: J Minfile Samples

Sample	Rock Type	Nearest KP
06-J-001	altered volcanic rock	525 m west of KP 1144.5
06-J-002	altered intrusive (granodiorite)	525 m west of KP 1144.5
06-J-003	altered volcanic rock	460 m west of KP 1144.5

The J copper-gold showing is exposed in two locations: on the south side of the Wedeene River, under the Canadian National railway bridge, and along a railway cut approximately 50 m south of the bridge. At the western outcrop, sulphide mineralization (pyrite and trace chalcopyrite) is disseminated at the subhorizontal contact of the underlying chloritically-altered Telkwa Formation volcanic rocks (O6-J-001) and an overlying intrusion (06-J-002). Irregular quartz-epidote-chlorite-calcite veinlets occur at the contact in both rock types, as does rusty weathering on fracture surfaces. A sample from each of the altered volcanic and intrusive rock was collected. At the exposed railway cut, a second sample of the volcanic rock was collected where sulphide mineralization content was visually estimated at 1% (06-J-003).

The paste pH values of the three samples ranged from 8.4 to 9.2, with total sulphur content between 0.02% and 0.3%, NP values between 6.3 and 27.0, and corresponding NPR values of 1.8 to 10. No elements exceeded the screening threshold for the respective rock types.

The intrusion and 06-J-001 (volcanic rock) samples are classified as NAG. The volcanic sample collected from the railway cut (06J-003) is considered to have a low potential for ARD.

6.5 Southeast Side of Hoult Creek

Table 6.5 contains a summary of samples collected from the southeast side of Hoult Creek.

Table 6.5: Southeast Side of Hoult Creek Samples

Sample	Rock Type	Nearest KP
06-Hoe-001	aphanitic volcanic	200 m west of KP 1093
06-Hoe-002	diorite dyke	200 m west of KP 1093

On the southeast side of Hoult Creek, a borrow pit has been excavated into a volcanic unit (06-Hoe-001) intruded by diorite dykes (06-Hoe-002). The overall sulphide content in the volcanic rock was visually estimated at <1%, and up to 2% in the dykes. Paste pH of the samples was 9.1 for the dyke and 9.3 for the volcanic rock respectively. Sulphide sulphur values for each of the rock types are 0.05% and 0.08%, NP values were 8.9 and 13.0, and NPR values were 5.7 and 5.2, respectively. Both samples are classified as NAG. No elements exceeded the screening threshold for the respective rock types.

6.6 Hoult (Minfile # 103I 164)

Table 6.6 contains a summary of samples collected from the Hoult (Minfile# 103I 164) area.

Table 6.6: Hoult Minfile Samples

Sample	Rock Type	Nearest KP
06-Hoult-001	chlorite-epidote altered volcanic	400 m north of KP 1088.5
06-Hoult-002	granitic intrusion	490 m west of KP 1088
06-Hoult-003	granitic intrusion	590 m west of KP 1088
06-Hoult-004	intense altered granitic intrusion	70 m northeast of KP1088
N-30I	granitic intrusion (monzonite)	210 m southwest of KP 1089
N-30K	granitic intrusion (monzonite)	210 m northeast of KP 1089
N-30L	granitic intrusion (monzonite)	445 m west of KP 1088
N-30M	granitic intrusion (alaskite)	200 m west of KP 1088

The Hoult copper-molybdenum showing is exposed in a clear cut logging block north of the proposed alignment. Logging road construction at this site has exposed an intrusion of the Coast Plutonic complex (06-Hoult-002 and -003) in contact with the Telkwa Formation chlorite-epidote altered volcanic rocks (06-Hoult-004). Pyrite and chalcopyrite occur in quartz veinlets and as blebs in the altered volcanic rock, yielding an overall visible sulphide content of <2%, with up to 5% sulphides in the veinlets. In the intrusion, disseminated to clotted or dendritic pyrite is present, and locally comprises up to 4% of the rock. Quartz veins with clotty pyrite,

molybdenite and chalcopyrite occur in the intrusion near the volcanic rock contact. Both rock types are cut by a series of fine-grained dykes, some of which are weakly magnetic. Alteration and sulphide mineralization are more strongly developed within both the granitic intrusion and the volcanic rocks near their mutual contacts, and near contacts with the magnetic dykes. Molybdenite coatings on fractures within the granitic intrusion appear to be spatially related to the weakly magnetic dykes. A sample of the mineralized volcanic rock and two samples of the granite were collected.

At the west edge of the adjacent clear cut block approximately 700 m east of the Hoult showing, there is an intensely altered granite outcrop (06-Hoult-004). Pervasive sericite/clay–pyrite alteration is developed around a small fault zone which strikes 120^o and dips 85^o SW. The intrusive rock is decomposed to clay and residual quartz with semi-massive fine-grained pyrite, and is stained with rusty weathering. The altered exposure is less than several square meters in area and cannot be traced further due to lack of outcrop. A sample of this material was collected for ARD testing.

In general, sulphide mineralization occurs in both the volcanic and intrusive rocks near the Hoult showing and appears to be most intense around their contacts. The NW-SE striking faults in the area may also have associated sulphide alteration.

The volcanic rock sample had a paste pH of 7.3, a sulphide sulphur content of 0.4%, NP value of 9.6, a resultant NPR value of 0.9, and is therefore PAG.

The intrusive rock samples had paste pH ranging from 7.5 to 8.9, sulphide sulphur content between 0.1% and 0.5%, NP values of 0.3 to 7.5 and NPR values of 0.1 to 0.5. The intrusive samples are considered to be NAG, except for the highly altered sample east of the showing which is PAG.

Molybdenum concentrations range from 15.1 to 58.9 mg/L and are highest in the altered volcanic rock, in excess of the screening threshold for the rock types. Chromium (125 mg/L) and silver (0.5 mg/L) exceed the screening threshold in the intrusive rock.

Detailed mapping was undertaken by the project team during the summer of 2006, in the vicinity of the proposed Nimbus Mountain and Hope Peak tunnels. Of the four samples collected near the Hoult copper-molybdenum showing, only one is considered to be PAG (N-30M).

6.7 Nimbus Mountain / Nimbus Ridge

Table 6.7 contains a summary of samples collected from the Nimbus Mountain and Nimbus Ridge area.

Table 6.7: Nimbus Mountain / Nimbus Ridge Samples

Sample	Rock Type	Nearest KP
Nimbus Ridge	fragmental volcanic	100 m northeast of KP 1082

The peak of Nimbus Mountain is composed of Middle Member Telkwa Formation volcanic rock with localized iron and copper staining and 1 to 2% disseminated visible sulphides. A sample collected from the site had a paste pH of 7.5, sulphide sulphur content of 0.4%, an NP value of 14.6, and an NPR value of 1.1. No elements exceeded the screening threshold. The NPR and sulphide sulphur values of the sample indicate that the rock outcropping on Nimbus ridge is PAG.

6.8 Ridge above Clore River Canyon

Table 6.8 contains a summary of samples collected from the ridge above Clore River Canyon.

Table 6.8: Ridge above Clore River Canyon Samples

Sample	Rock Type	Nearest KP
06-CloreR-001	andesitic volcanic	380 m west of KP 1075
06-CloreR-002	fragmental volcanic/rhyolite	210 m southeast of KP 1076

An exposed outcrop on the ridge south of the Clore River contains several rock units including a volcanic rock (andesite, 06-CloreR-001)) with ~1% pyrite/pyrrhotite that is overlain by a fragmental volcanic rock and rhyolite (06-CloreR-002). Veinlets of pyrite-pyrrhotite-chalcopyrite+magnetite occur at the fragmental volcanic/rhyolite contact. Visible sulphide content is up to 2%. A felsic intrusion is also present, but visible sulphides were not identified so no sample was collected. Sulphide sulphur contents for the sulphide-bearing andesite and rhyolite samples were both 0.3% and NP values were 14.3 and 9.8 kg $CaCO_3$/tonne. Corresponding NPR values of 1.3 and 1.1 indicate that both samples are PAG. Molybdenum (9.5 mg/L) exceeded the screening threshold in the andesite sample.

6.9 Nanika Intrusion, Confluence of Burnie and Clore Rivers

Table 6.9 contains a summary of samples collected from the Nanika Intrusion at the confluence of the Burnie and Clore Rivers.

Table 6.9: Nanika Intrusion, Confluence of Burnie and Clore Rivers Samples

Sample	Rock Type	Nearest KP
06-Int-001	aphanitic volcanic	285 m southwest of KP 1071
06-Int-002	aphanitic volcanic	130 m southwest of KP 1071

The proposed pipeline route skirts around a topographic high situated 1.5 km east of the confluence of the Burnie and Clore Rivers. This knob is mapped as a small stock (approximately 3 km^2) belonging to the Nanika Plutonic Suite, but is covered in fine-grained dark grey volcanic rock with possible calcite-filled amygdules.

The two samples of volcanic rock that were collected had paste pH values of 8.1 and 8.5, sulphide sulphur contents that range from below detection to 0.08%, high NP values of 92.5 and 28.8, and corresponding NPR values of 37.0 and 95.8. These rocks are considered NAG. No elements exceed screening criteria thresholds.

6.10 Red Rose Formation

Table 6.10 contains a summary of samples collected from the Red Rose Formation

Table 6.10: Red Rose Formation Samples

Sample	Rock Type	Nearest KP
06-Rose-001	black shale	2.0 km southwest of KP 1072
06-Rose-002	hornblende-plagioclase dyke	1.9 km southwest of KP 1072
06-Rose-003	very fine-grained sandstone	340 m southwest of KP 1072
06-Rose-004	fine-grained siltstone	1.0 km south of KP 1072
06-Rose-005	dark volcanic	1.1 km northwest of KP 1069

Several outcrops were visited near the Burnie River where the Red Rose Formation was mapped. At the southernmost site east of the Burnie River, very fine-grained cubic pyrite porphyroblasts and iron carbonate concretions are present on black shale bedding planes and within the rock matrix (06-Rose-001). Samples were collected of the black shale, likely belonging to the Red Rose Formation and a sample of one of several dykes that intrude the shale and contain up to 5% disseminated pyrite (06-Rose-002). The black shale sample had a paste pH of 5.7, a sulphide content of 0.02%, an NP value of 0.2 kg $CaCO_3$/tonne, and a resulting NPR of 0.4. Due to the low sulphide contents, the shale is considered to be NAG. Arsenic (168 mg/L) exceeds the screening threshold for shales. The dyke had a paste pH of 8.2, a sulphide sulphur content of 0.5%, an NP of 73.3 and an NPR of 4.9. It is not considered acid generating, and no elements exceeded the screening thresholds.

The second outcrop was located on the west side of the Burnie River. The outcrop along the river consisted of a dirty, unsorted sandstone and siltstone with possible trace fossils. On the opposite side of the river, there appeared to be black shale, which suggests there is a northerly trending contact between these rock types that the Burnie River partially follows. Two samples of the clastic rocks were collected (06-Rose-003 and -004). These samples have paste pH of 8.2 and 6.1, and contain 0.08 and 0.04% total sulphur, respectively. The sandstone sample has an NP value of 18.8 and a corresponding NPR of 7.5. Based on the values it is classified as NAG. Molybdenum (3.8 mg/kg), nickel (36.7 mg/kg) and arsenic (5 mg/kg) exceed the screening criteria for a sandstone composition. The siltstone sample has a negative NP value, possibly due to the presence of soluble acid sulphate minerals. Molybdenum (1.5 mg/L) and arsenic (12 mg/L) exceed the screening criteria for a siltstone composition. Although the NP is negative, the siltstone is considered NAG due to the low sulphide sulphur concentrations and a paste pH greater than 5.5.

The northernmost site was along a prominent volcanic ridge 0.5 km east of the Burnie River, and approximately 2 km north of the alignment. White calcite veins within the outcrop were moderately abundant (06-Rose-005). The volcanic rocks were cut by a limited number of dykes that contain minor amounts of disseminated pyrite and are similar to those observed to cut the shales at the first Red Rose site. A sample of the volcanic rocks was collected. This sample had a paste pH of 8.3, undetectable sulphide content, an NP of 14.6 and a corresponding NPR of 48.6. This sample is NAG and no elements exceeded the screening criteria.

6.11 Copper Star (Minfile# 093L 326)

Table 6.11 contains a summary of samples collected from the Copper Star (Minfile# 093L 326) area.

Table 6.11: Copper Star Minfile Samples

Sample	Rock Type	Nearest KP
Copper Star	no sample collected	4.5 km north of KP 1032

An outcrop on the Copper Star showing was exposed in a moderately magnetic intrusive rock 1.5 km north of the proposed pipeline route along a logging road in an area of subdued topography and sparse outcrop. Minor amounts of chalcopyrite with malachite staining occur in sparse blebs. Approximately 200 m east along the logging road, volcanic rocks with sparse quartz veins containing trace amounts of pyrite are exposed. Additionally, a stack of drill core was located in a clearing just north of KP 1032. Core samples consist of volcanic rock that contains pyrite-coated fractures and pink and white calcite-coated fractures. The original location of these drill holes is unknown so no sample was collected. The Copper Star showing was not sampled because of its distance from the alignment and the subdued topography. Sample 06-Telkwa-002 was taken south of the Copper Star. Results of this sample are discussed in Section 6.12.

6.12 Volcanic Rocks

Table 6.12 contains a summary of samples collected from volcanic rocks near KPs 1010, 1019, and 1030.5.

Table 6.12: Volcanic Rocks Samples

Sample	Rock Type	Nearest KP
06-Telkwa-001	bedded andesitic flows	3.0 km northwest of KP 1017
06-Telkwa-002	fragmental volcanic rock	3.4 km north of KP 1030.5
06-Mor-001	fragmental volcanic rock	4.8 km north of KP 1010

Andesitic volcanic rocks were examined at three separate sites along the route near KPs 1010, 1019 and 1030.5. The westernmost site near KP 1030.5 consists of massive, hematite-altered fragmental volcanic rock. A sample of the outcrop was collected (06-Telkwa-002) and is thought to be more representative of the rock that may be encountered during pipeline construction than the altered volcanic rocks of the Copper Star showing (Section 6.11). The second site (near KP 1019) is a large (120 m x 25 m) cliff exposure of well bedded volcanic rocks and minor intercalated sediments. The outcrop is intensely fractured with abundant calcite coated fractures and less frequent cross cutting calcite veins. There is a large apron of colluvium at the base of the cliffs that has been cemented with calcite. A sample (06-Telk-001) was collected near the base of the cliff avoiding the calcite cemented material.

The third, easternmost site (KP 1010) is a ridge of fragmental volcanic rock outcrop in an otherwise overburden covered area. A sample of the fragmental rock was collected (06-Mor-001).

These three volcanic samples had paste pH values ranging from 7.3 to 8.6, undetectable levels of sulphide sulphur, NP values of 4.9 to 138.7, and NPR values of 16.2 to 462.4. These are classified as NAG. No elements exceeded the screening threshold for andesitic rocks.

6.13 Chisholm Lake/Goldstream (Minfile# 093L 159 / 093L 160)

Table 6.13 contains a summary of samples collected from the Chisholm Lake/Goldstream (Minfile# 093L 159 / 093L 160) areas.

Table 6.13: Chisholm Lake/Goldstream Minfile Samples

Sample	Rock Type	Nearest KP
Chisholm Lake	no sample collected	5.6 km north of KP 1027
Goldstream	no sample collected	2.32km north of KP 1026
outcrop	no sample collected	3.5 km northwest of KP 1026

The Chisholm Lake and Goldstream occurrences are coal showings in the Hazelton and Skeena Groups, respectively. Both showings are highly localized with thin coal seams; a maximum width of 1.7 m is recorded for Goldstream and coal was not encountered during down-dip drilling of the outcropping seam.

There is very little outcrop in the vicinity of the Chisholm Lake showing, though logging has provided access to some exposure which consists of a medium-grained arkose. The original coal seam of interest at this site was not located, and no sample was collected.

In the area of the Goldstream showing, a clear cut block contains large (>20 m^3) blocks of a similar dirty arkosic rock as that seen at the Chisholm Lake showing. A few black fragments of possible plant material were also observed, but no coal seams were located. The large blocks do not appear to be in place, and as such, no sample was collected.

6.14 Silver Streak (Minfile# 093L 327)

Table 6.14 contains a summary of samples collected from the Silver Streak (Minfile# 093L 327) area.

Table 6.14: Silver Streak Minfile Samples

Sample	Rock Type	Nearest KP
06-Streak-001	andesite volcanic	1.8 km south of KP 995

A small quarry pit adjacent to a logging road near the documented location of the Silver Streak showing consists of andesite rock with iron staining and no visible sulphides. Opaline quartz and bladed calcite veins cut the andesite. This rock type does not match the MINFILE description of the Silver Streak occurrence, and it is possible the actual showing has been covered or destroyed.

The paste pH of this sample was 8.4, and sulphide sulphur content was undetectable. NP was 59.1 with an NPR of 197.0. This sample is NAG and no elements exceeded the screening criteria. However, the potential for sulphide-bearing rock in this area has not been eliminated due to the discrepancy of the MINFILE description and the rock types encountered in the field.

6.15 Bulkley Intrusion

Table 6.15 contains a summary of samples collected from the Bulkley Intrusion area.

Table 6.15: Bulkley Intrusion Samples

Sample	Rock Type	Nearest KP
06-Bulk-001	felsic intrusion	200 m east of KP 987

The proposed pipeline route crosses small stocks of the Bulkley Intrusive Suite, a small exposure of which was located along a road 200 m east of KP 987.

Sample 06-Bulk-001 had a paste pH of 8.8, undetectable total sulphur content, an NP value of 16.3 and an NPR value of 54.2. No elements exceeded the screening criteria. This particular intrusion is NAG, however the Bulkley intrusive suite is known to host copper-molybdenum deposits and is considered to be a permissive unit.

6.16 Klo River and Volcanics West of Equity Silver Mine

Table 6.16 contains a summary of samples collected from the Klo River area and Volcanics West of Equity Silver Mine.

Table 6.16: Klo River and Volcanics West of Equity Silver Mine Samples

Sample	Rock Type	Nearest KP
06-Klo-001	andesite volcanic	460 m southeast of KP 975
06-EMW-001	red andesite/basalt flow	500 m east of KP 969
06-EMW-002	grey andesite/basalt flow	500 east of KP 969

Twelve kilometres east of Equity Silver Mine, an 80 m long outcrop of volcanic rocks exposed along a road cut at Klo Creek was examined and sampled (06-Klo-001). Trace amounts of pyrite associated with magnetite in andesite were observed. The paste pH of this rock was 8.7, total sulphur content was below detection limits, NP was 29.8, and NPR was 99.2. The sample is considered to be NAG.

The second site examined is a prominent bluff of layered volcanic rocks that occur approximately 7 km west of the mine site. Samples of these flows (06-EMW-001 and -002) had paste pH values of 7.6 and 8.4, sulphide sulphur contents of 0.02 and 0.03%, NP values of 16.3 and 17.0 and NPR values of 17.3 and 56.7. The samples are NAG and no elements exceed the screening criteria.

6.17 Equity Silver (Minfile# 093L 001)

Table 6.17 contains a summary of samples collected from the Equity Silver (Minfile# 093L 327) area.

Table 6.17: Equity Silver Minfile Samples

Sample	Rock Type	Nearest KP
06-EM-001	grey volcanic	1.2 km south of KP 961.5
06-EM-002	green volcanic	210 m southwest of KP 960.5
06-EM-003	green volcanic	50 m southwest of KP 960
06-EM-004	dark intrusive with phenocrysts	230 m south of KP 959.5
06-EM-005	dark intrusive with phenocrysts	230 m south of KP 959.5
06-EM-006	highly altered volcanic	230 m south of KP 959.5
06-EM-007	green volcanic	170 m southwest of KP 960.5

The alignment near the Equity Silver Mine is in an area dominantly underlain by shallowly dipping intermediate volcanic flows that are covered in many areas by alluvium, and as such there is very little outcrop in the valley. These volcanic rocks are generally low in sulphides. Numerous sites were visited in and around the Equity Silver mine.

East from the Equity Silver tailings dam and south of the alignment, seven samples were collected from numerous locations that include a diversion ditch, Foxy Creek, and logging roads. These rocks consist of fine-grained grey volcanic and dark porphyritic rocks. Sample 06-EM-006 was collected from a small exposure (less than 3 m^2) of intensely pyrite-altered porphyritic rock around KP 958-961.

Paste pH values ranged from 3.7 to 8.5, sulphide sulphur contents ranged from 0.05 to 2.4%, NP values range from 3.8 to 89.9, and NPR values range from 0.1 to 16.8. Three samples (06-EM-004, -005 and -006) are PAG. The remaining samples are considered NAG (06-EM-001, -002, -003 and -007). Arsenic concentrations exceeded the screening criteria for rock type abundances in samples 06-EM-003, -005 and -006, ranging from 10 to 49.9 mg/L. Mercury (0.66 mg/L) exceeded the screening criteria in sample 06-EM-006.

Two borrow pits were also examined. The first being directly east of the tailings dam, near sample 06-EM-001, the second borrow area being northwest of the mine site and adjacent to the mine access road. The rocks are a series of flows and dykes similar in texture and composition. No sulphides were observed and no samples were collected.

6.18 Volcanic Rocks East of Equity Silver Mine

Table 6.18 contains a summary of samples collected from volcanic rocks east of Equity Silver Mine.

Table 6.18: Volcanic Rocks East of Equity Silver Mine Samples

Sample	Rock Type	Nearest KP
06-Foxy-001	basalt/andesite volcanic	1.2 km north of KP 957
06-Endak-001	basalts volcanic	2 km north of KP 954
06-Endak-002	tuffaceous basalt layers	990 m north of KP 954

Outcrops in the steep Foxy Creek canyon were also investigated approximately 1.2 km north of the Rev R alignment where layered basaltic flows are exposed on both sides of the valley down to the creek bed (06-Foxy-001). No sulphides were observed. The paste pH of this rock was 7.8 and no sulphide sulphur was detected in the sample (06-Foxy-001). The negative NP value (-15.3 kg $CaCO_3$/t) may be related to the presence of acid sulphate minerals. However, laboratory results did not report sulphate concentrations greater than the detection limit.

Nine kilometres east of the mine site, a few knobs of vesicular basalt flows and laminated, buff-coloured tuffaceous interbeds are exposed in a cut block 1.0 to 2.0 km north of the alignment (06-Endak-001 and -002). The paste pH of these samples ranged from 6.9 to 8.1, sulphide sulphur content ranges from undetectable to between 0.04% and 0.02%. Analytical NP results ranged from a minimum of -4.0 to a maximum of 13.8 kg $CaCO_3$/t. Although the NP values are very low to negative, the samples are not expected to be acid generating as there are insufficient concentrations of sulphides. The samples with negative NP have no capacity to neutralize acid or to generate acid. The 09-Foxy-001 sample had a positive NP, no detectable sulphide and is classified as NAG. No elements exceeded the screening criteria for basaltic rocks.

6.19 Hanson Lake (Minfile# 093K 078)

Table 6.19 contains a summary of samples collected from the Hanson Lake (Minfile# 093K 078) area.

Table 6.19: Hanson Lake Minfile Samples

Sample	Rock Type	Nearest KP
06-Hanson-001	drill core, altered rhyolite dyke	180 m southeast of KP 877.5
06-Hanson-002	drill core, mineralized gneiss	180 m southeast of KP 877.5
06-Hanson-003	subcrop gneiss	590 m southwest of KP 878

The Hanson Lake copper showing lies approximately 1 km to the south of the proposed pipeline alignment in an area of very little outcrop. There was no access to the Hanson Lake showing itself, however drill core from a 1990 drilling investigation was found stacked adjacent to a logging road. In the core, the main country rock is gneiss with localized, disseminated and veinlet controlled mineralization consisting of pyrite-chalcopyrite and possibly bornite associated with chlorite-epidote-calcite alteration (06-Hanson-002). Visible sulphide content is locally up to 5%. The gneiss is cut by a quartz-plagioclase rhyolite porphyry with a white siliceous, altered groundmass, and 1-2% very fine-grained disseminated cubic pyrite (06-Hanson-001).

Paste pH values of the rhyolite and gneiss samples were 7.9 and 8.7, respectively. Sulphide sulphur contents were 0.5%, and 1.7%. NP values ranged from 4.3 to 41.3. The drill core samples had NPR values of 0.3 and 0.2, and are therefore considered to be PAG. Lead (517.1 mg/L), zinc (1487 mg/L), silver (0.9 mg/L) and cadmium (15.7 mg/L) exceeded the screening criteria for the rhyolite. Copper (1877.2 mg/L) in the mineralized gneiss exceeded the screening criteria.

An area of subcrop/outcrop biotite gneiss was examined on a stretch of road running sub-parallel to the alignment, approximately 600 m southwest of KP 878. The gneiss was partially epidote altered and contained <1% disseminated pyrite (06-Hanson-003). Sulphide sulphur content was below detection and the rock is considered to be NAG. No elements exceeded the screening criteria in the outcrop sample.

The Hanson Lake area is generally overlain by alluvium, outcrop is sparse and the extent of mineralization related to the Hanson showing is unknown.

6.20 Misinchinka Group - Missinka River

Table 6.20 contains a summary of samples collected from the Misinchinka Group at Missinka River.

Table 6.20: Misinchinka Group – Missinka River Samples

Sample	Rock Type	Nearest KP
06-Miss-001	silver grey phyllite	900 m south of KP 661
06-Miss-002	silver grey phyllite	860 m southwest of KP 661
06-Miss-003	orthoquartzite-schist	115 m west of KP 662.5
06-Miss-004	orthoquartzite-schist	120 m east of KP 662.5
06-Miss-005	silver grey phyllite	430 m southeast of KP 653
06-Miss-006	silver grey phyllite,	400 m southeast of KP 652

Several sites were examined both north and south of the Missinka River between KP 652 and 660, where bedrock was intermittently exposed along logging roads over approximately 8 km. The rocks are an alternating sequence of pale silver-grey phyllite (06-Miss-001, -002, -005 and -006) and coarse-grained schist (06-Miss-003 and -004), apparently derived from quartz pebble conglomerates. Pyrite porphyroblasts generally <3 mm across are disseminated throughout the phyllite, ranging from minor amounts up to 10%. The coarse-grained schist forms resistant knobs cut by abundant white quartz veins up to several meters in thickness, but of limited strike length. No sulphides were observed in the veins and there are generally only trace amounts of sulphides present in the schist.

Several samples of both rock types were collected. The paste pH values ranged from 6.8 to 8.0. Sulphide sulphur content values ranged from below detection to 0.6%. All samples are NAG, except the PAG high sulphide phyllite sample (06-Miss-002). Both the phyllite and schist have low NP values (range -6.4 to 3.8) and the PAG classification would likely be highly susceptible to zones of higher sulphide content. No elements exceeded the screening criteria for the appropriate rock type.

6.21 Miette Formation

Table 6.21 contains a summary of samples collected from the Miette Formation.

Table 6.21: Miette Formation Samples

Sample	Rock Type	Nearest KP
06-Miette-001	black shale/ argillite	180 m east of KP 641.5
06-Miette-002	black shale/ argillite	1 km south of KP 646
06-Miette-003	black shale/ argillite	65 m southwest of KP 646.5
06-Miette-004	black shale/ argillite	40 m northeast of KP 646.5
06-Miss-007	dark grey argillite	250 m north of KP 644
DC py	dark grey argillite	1.1 km south of KP 646

Black pyritic shale and silver argillite outcrops of the Miette Formation were examined at four sites along logging roads, including a small borrow pit south of KP 646, and one site in a large quarry near KP 641. The sites are distributed over approximately 5 km. The pyritic shale is fissile and highly iron-stained due to abundant coarse-grained quartz-pyrite veins and disseminated euhedral pyrite. Overall pyrite content is up to 10%, with much higher concentrations in veins, which are up to several centimetres thick. A pool of standing water in the black shale borrow pit for the road bed material had a field pH of 3.5 adjacent to sample 06-Miette-002.

The paste pH of these samples ranged from 3.0 to 9.1 and sulphide sulphur content varied from 0.04% in an intensely weathered sample to 23% in fresh pyritic vein material. NP values for four of the samples are negative (06-Miette-002, -003, -004 and 06-Miss-007). 06-Miette-001 had an NP of 68.4 and NPR of 5.2 and is considered NAG. Two additional, low sulphide samples are considered NAG (06-Miette-003 and 06-Miss-007). The remainder of the samples are PAG (06-Miette-001, -002, -004 and DC py).

Arsenic values far exceeded the threshold value for shale in the pyritic samples (246.0 to 443.2 mg/L). The PAG black shale rock unit is easily distinguished in the field from the NAG material based on its jet black colour and abundant quartz-pyrite veins.

6.22 Besa River and Palliser Formations

Table 6.22 contains a summary of samples collected from the Besa River and Palliser Formations.

Table 6.22: Besa River Formation and Palliser Formation Samples

Sample	Rock Type	Nearest KP
06-Besa-001	black shale with pyrite	1.0 km southeast of KP 604
06-Besa-002	black shale with pyrite	1.2 km southeast of KP 604
06-Besa-003	fossiliferous limestone	460 m northeast of KP 606
06-Besa-004	siltstone/shale	460 m northeast of KP 606

Approximately 1 km south of KP 604, a large exposure of the known pyrite-bearing Besa River Formation outcrops in Imperial Creek. The rock is dominantly black carbonaceous shale with extensive iron staining and white and yellow sulphate precipitates. The iron staining was likely caused by weathering of pyrite/marcasite concretions which range from <1 cm up to 30 cm in diameter. The nodules are highly reactive and coated in white sulphur-oxides or salts. The nodules are not evenly distributed within the shale but appear to be confined to certain horizons that are a few tens of cm in thickness. However the rusty staining is widespread on fracture/foliation surfaces. The pyrite/marcasite nodules are extremely fine-grained and concentrically banded. A few bedding parallel, pyrite-rich lamina were also observed but were rare. Two samples (06-Besa-001, -002) collected at this locality had paste pH values of 6.5 and 4.9, sulphide sulphur contents of 2.0% and 1.6%, and NP values of 9.9 and 0.9, respectively. NPR values less than 1 indicate that both of these samples are PAG. Molybdenum (51.6 mg/L, 58.5 mg/L) and cadmium (3.2 mg/L, 2.8 mg/L) in both samples and arsenic (82.7 mg/L) in sample 06-Besa-001 exceeded the screening criteria.

The Palliser Formation was examined in a road cut northwest of Imperial Creek, directly on the alignment. Fissile grey-black siltstone/shale is exposed on the east side of a ridge where the Palliser Formation outcrops. No pyrite nodules were observed, however, there were completely weathered out pits, which could have been pyrite porphyroblasts. Sample 06-Besa-004 had a paste pH of 6.8, sulphide sulphur content of 0.2%, NP of 3.1 and an NPR of 0.5, indicating it is NAG. Molybdenum (26.8 mg/L) exceeded the screening criteria for this rock type.

West of the shale along the same outcrop ridge, fossiliferous limestone is exposed. The limestone contains undeformed rugose and branching coral fossils, bivalves and pieces of crinoid stems. White calcite veins have formed in the limestone. The paste pH of this sample was 8.6, sulphide sulphur content was 0.02%, NP was 830.6, and NPR was 1329. The sample was NAG and no elements exceeded the screening criteria.

6.23 Muskiki Formation

Table 6.23 contains a summary of samples collected from the Muskiki Formation.

Table 6.23: Muskiki Formation Samples

Sample	Rock Type	Nearest KP
06-MuskN-001	sandstone outcrop on forestry road	3.1 km north of KP 554
06-MuskN-002	siltstone with pebble clasts	3.2 km north of KP 554
06-Smoky-001	immature sandstone	730 m southeast of KP 553

Outcrops and subcrops in two cut blocks near the alignment were examined to locate the known pyrite-bearing Muskiki Formation. The first outcrop is 3 km north of the route and consisted of sandstone/siltstone subcrop with no visible sulphides (06-MuskN-001 and -002). The second outcrop is to the south, adjacent to the alignment and consists of immature sandstones (06-Smokey-001). The contact with the black shale unit was not exposed.

The paste pH of the three samples collected ranged from 6.9 to 8.0, sulphide sulphur content ranged from below detection to 0.04%, and NP values ranged from 0.4 to 32.0. The samples are considered to be NAG. Molybdenum (3.1 mg/L, 6.8 mg/L) and nickel (10.6 mg/L, 20.6 mg/L) exceeded the screening criteria in two of the samples and arsenic (7 mg/L) was exceeded in one sample.

6.24 Clore River and Nimbus Mountain Areas

Table 6.24 contains a summary of samples collected from the Clore River and Nimbus Mountain areas.

Table 6.24: Clore River and Nimbus Mountain Samples

Sample	Rock Type	Nearest KP
N-13I	quartz monzonite	370 m southeast of KP 1106
N-17B	volcanic tuff	360 m west of KP 1104
N-17C	andesite flow volcanic	80 m southwest of KP 1104
N-17H	andesite flow volcanic	130 m southeast of KP 1101
N-30C	monzonite dyke	270 m east of KP 1094
N-32E	fault breccia	1.1 km north of KP 1079
N-33D	andesite tuff and flows	730 m southwest of KP 1079
N-9O-2	monzonite dyke	520 m east of KP 1115
N-9L-2	diorite dyke	350 m east of KP 1116

Detailed mapping was undertaken by the project team during the summer of 2006, in the vicinity of the proposed Nimbus Mountain and Hope Peak tunnels. Results of this project are reported under separate cover. The mapping team collected surface grab samples for ARD testing as an adjunct to the primary mapping project. A subset of these samples was submitted for ABA and metal analyses to supplement this study. The samples are representative of rocks exposed along the logging road that accesses the north side of Hoult Creek, Nimbus Mountain, and the west portal of the Hope Tunnel. The rocks consist of Telkwa Formation and Hazelton Group volcanic rocks intruded by granitic rocks, some of which belong to the Bulkley intrusive suite. Thirteen rock samples were selected for analyses based on the presence of visible sulphides.

The samples have paste pH values ranging between 8.5 and 9.2, and sulphide sulphur contents from below detection to 0.4%. NP values range from 7.2 to 201.0. NPR values range from 1.9 to 49.2. The samples are considered to be NAG.

7.0 DISCUSSION OF FINDINGS

7.1 Potential ARD Areas

A GIS-based interpretation of available data identified areas potentially permissive to the occurrence of ARD along the alignment. This includes known mineral occurrences (Model 1), reported pyritic units (Model 2) and geology permissive to the occurrence of ARD (Model 3). The results of the GIS interpretation are listed in Table 7.2. Potential ARD areas are distributed across the western portion of the alignment and within the Rocky Mountains to the east, as illustrated in Figure 6. Known mineral occurrences (Model 1, or MINFILE occurrences) dominate the western portion of the alignment, whereas pyritic units (Model 2) dominate the eastern portion of the alignment near the Rocky Mountains.

7.2 Potential ARD Sites

A summary of the results of the August 2006 field investigation of potential ARD sites is shown in Table 7.1. Results were classified as PAG or NAG and then assessed relative to the alignment taking into account surficial geology and topography. Detailed results were discussed above in Section 6 and are contained in Appendix A. Detailed field site descriptions are contained in Appendix B. The potential ARD sites are an amalgamation of the potentially permissive areas outlined above and additional sites characterized due to either proximity to the pipeline alignment or visual indications of acid drainage.

Table 7.1: Summary of Potential ARD Areas along the Alignment

Site Name	Lithology/Commodity	Nearest KP	Model
Known Mineral Occurrence			
Joan	Cu skarn	1156	1
Barite	Volcanogenic barium	1149	1
Billy	Au pyrrhotite veins	1149	1
J	Massive sulphide Cu-Pb-Zn	1145	1
Wedeene	Fe skarn	1144	1
R&F	Cu	1121	1
Hoult	Porphyry Mo	1089	1
Sal	Volcanic redbed Cu	1075	1
Copper Star	Porphyry Cu +/- Mo +/- Au	1032	1
Chisholm Lake	Bituminous coal	1030	1
Goldstream	Bituminous coal	1026	1
GSC 1971-14	Volcanic redbed Cu	1014	1
Silver Streak	Ag	995	1
Irk	Ag-Pb-Zn +/- Au veins	987	1
Equity Silver	Subvolcanic Cu-Ag-Au	960	1
Hanson Lake	Porphyry Cu +/- Mo +/- Au	877.5	1
Pyrite-bearing rock unit			
Skeena Group Red Rose Fm		1070-1072	2
Hazelton Gp Nilkitkwa Fm		1051-1063	2
Miette Group Miette Fm		637.5-647	2
Wabamun Group Besa River Fm		601-605.5	2
Smoky Group Muskiki Fm		551.5-552.5	2
Geology Permissive to ARD			
Poison Pluton	Cu, Fe	1120-1147	3
Unnamed intrusive	Mo, Cu, Ag	1029-1095 and 1106-1120	3
Coast Plutonic	Cu	1073-1079	3
Hazelton Gp Telkwa Fm	Cu, Pb, Zn, Au, Mo	993-1162	3
Kasalka Gp	Ag (+ Equity Silver mine)	992-994 and 1004-1111	3
Nechako Plateau Gp	Cu, Au	873.5-877.5 and 934-944	3
Endako Batholith	Coal, Cu, Cu-Mo	841-843.5	3
Takla Gp	Hg	790.5-800	3
Minnes Gp	Coal	570-580 and 581-588	3
Fort St. John Gp	Coal	564.5-566 and 568-569.5	3

Figure 7.1: Location Map of Potential ARD Areas along the Alignment

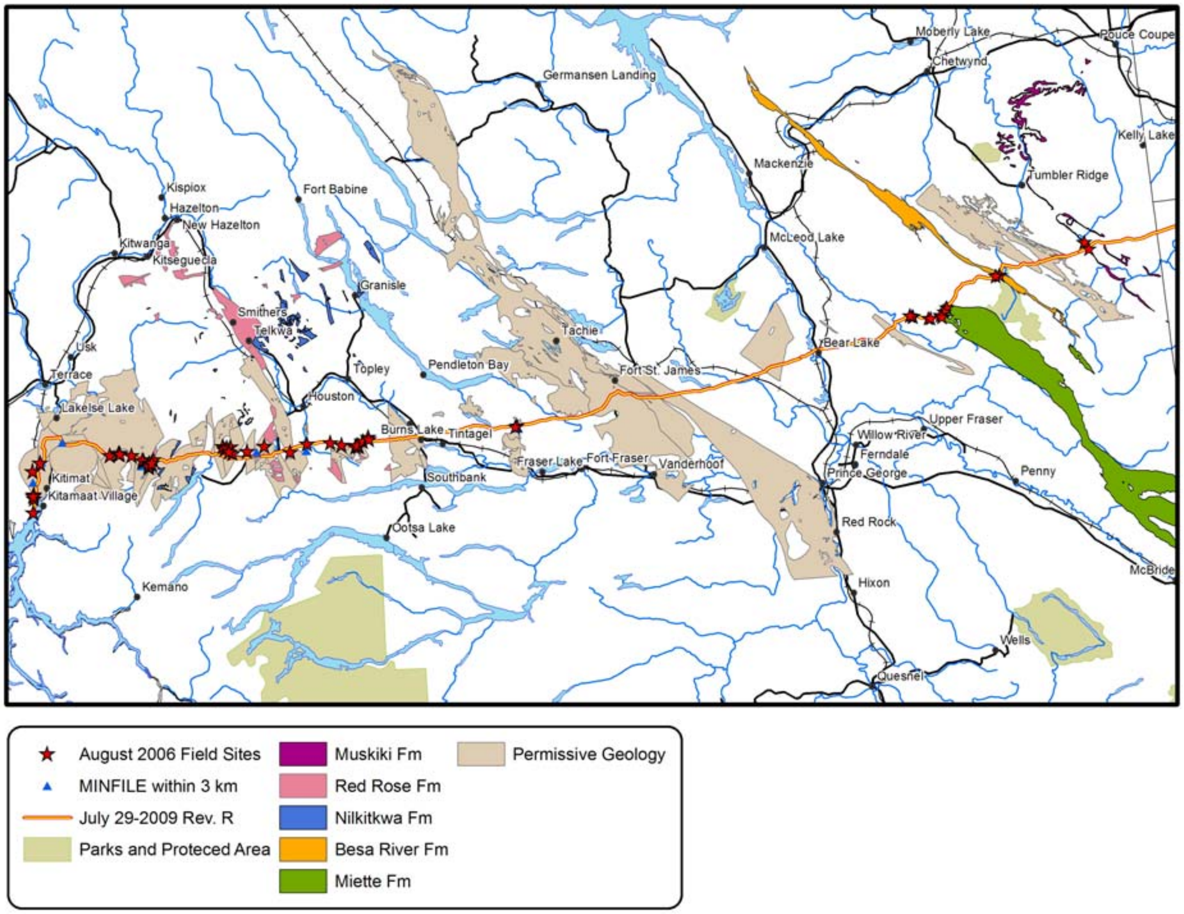


Table 7.2: Investigated Potential ARD Sites

Site Name	Description	Approx. KPs	PAG Classification	ARD Assessment Relative to Proposed RoW	Comments
Kitimat Terminal	Mafic volcanic rock, felsic dykes (<1%pyrite) and pyritic veins	1172	Mafic volcanic and pyrite dykes: Yes Felsic dykes: No	Possible	Terminal construction will require excavation of large volume of rock and will need investigation beyond scope of this work. Current assessment indicates that the mafic phase is an important ARD control parameter because of the large volume. The felsic dykes and pyrite bearing veins are less abundant.
West side of lower Kitimat Valley	Poison Pluton, Telkwa Volcanics (<1% pyrite)	1162-1165	No	Low	There were seven samples taken between KP 1152and 1158 with no visible sulphides that could be submitted for ABA analysis. Current sampling indicates low ARD potential in intrusive and volcanic rocks near the Alcan plant.
Billy MINFILE	Telkwa Volcanics with minor pyrite	2.4 km west of KP 1149	Yes	Low	Small sulphide showing several hundred meters uphill of RoW. No sulphides observed during traverse uphill to showing. Expect there will be no sulphides associated with this showing in excavations or exposures for pipeline construction.
Wedeene MINFILE	Not found	1144	Undetermined	Unknown	MINFILE site could not be found and site not assessed. ARD potential unknown.
J MINFILE	Intrusive and volcanic	1145	No	Low	Local observations suggest rock may not be exposed. ARD potential would increase if it is necessary to excavate into intrusive rocks that host disseminated sulphides.
R & F MINFILE	Not found	1121	Undetermined	Unknown	MINFILE site could not be found and site was not assessed. ARD potential unknown.
East Hoult Ck.	Volcanic(<1% pyrite) and dykes (2% pyrite)	1093	No	Low	RoW on west side of Hoult Creek opposite to this site.
Hoult MINFILE	Coast Plutonics and Telkwa Volcanics (2-5% pyrite)	1088-1089	Plutonic: No Volcanic: Yes	Likely - Possible	ARD potential may be significant in excavations or exposures on the slopes north of Hoult Creek. Localized zones of high sulphide and ARD potential possible (i.e. sample 06-Hoult-004). Note that molybdenum leaching is possible under neutral and alkaline conditions.
Nimbus Mountain	Volcanic	1081-1082	Yes	Likely	Sample of localized copper and iron staining that is not aerially extensive. Note that rusty red weathering was seen at contact of intrusive with overlying volcanic, but could not be accessed for sampling. ARD more likely near volcanic and intrusive contact.
Clore Ridge	Volcanic	1073-1079	Yes	Low	Sulphide veinlets observed at contacts of Telkwa volcanics with overlying more felsic volcanics. Field mapping indicated disseminated pyrite in Telkwa volcanics (Site N5l). ARD potential greater in volcanics and near contacts with intrusives.

Site Name	Description	Approx. KPs	PAG Classification	ARD Assessment Relative to Proposed RoW	Comments
Nanika Intrusion	Volcanic	1069-1071	No	Low	The alignment is not expected to intersect this unit.
Red Rose Fm. Burnie R.	Black Shale and dyke	1069-1072	No	Low	Abundant red rusty weathering, but low ARD potential. Consider submitting ARD samples N59 and N3F for ABA analysis.
Copper Star MINFILE	Intrusive and Volcanic	4 km northeast of KP 1032	Intrusive: No Volcanic: Yes	Low	This occurrence is 1.5 km north of RoW in an area of subdued topography and extremely limited outcrop. Sample 06-Telkwa-02 taken closer to alignment and has no ARD potential.
Volcanics	Fragmental and bedded volcanics	1010-1036	No	Low	Three samples in Hazelton Gp Telkwa Fm (also mapped as Skeena Gp sedimentary rocks, but field identification indicated volcanic rock type). The Telkwa volcanics often have red weathering but do not appear to be acid generating in most areas.
Chisholm Lk MINFILE	No outcrop	5.5 km northwest of KP 1026	Undetermined	Low (Unknown)	Area of subdued topography with extremely limited outcrop. Coal seam was not located, but reported to be 1.5 m thick.
Goldstream MINFILE	No outcrop	2.3 km northwest of KP 1026	Undetermined	Low (Unknown)	Area of subdued topography with extremely limited outcrop. Coal seam was not located. Coal seams reported to be 1.7 m thick.
Silver Streak MINFILE	Volcanic	1.8 km south of KP 995	No	Low (Unknown)	Quarry outcrop did not match MINFILE description. Although no sulphides were observed, this assessment cannot eliminate ARD potential.
Bulkley Intrusion	Intrusive	987	No	Low	Where sampled, no potential for acid drainage was identified. However, the unit is known to host sulphide mineralization in other locations and remains permissive for ARD. This assessment does not conclude all Bulkley intrusive rocks are non-PAG.
Klo River and Volcanics West of Equity	Volcanic	968-976	No	Low	The Buck Creek Fm aphanitic basaltic rocks have rusty red weathering (KP 947 to 972) but low acid generation potential. Numerous outcropping bedrock knobs along the alignment.
Equity and Foxy Creek	Volcanic and Porphyritic	957-966	Under Review	Possible	Current alignment and alternate do not appear to intersect Equity Silver Mine host rocks, but are likely to stay in volcanic package that has localized zones with disseminated pyrite and the potential for acid generation.
Volcanics East of Equity	Volcanic	953-958	Under Review	Low	Endako Gp. Volcanics east of the Equity Silver mine are not expected to be acid generating.

Site Name	Description	Approx. KPs	PAG Classification	ARD Assessment Relative to Proposed RoW	Comments
Hanson Lake MINFILE	Core Rhyolite, gneiss, subcrop gneiss	878.5	Subcrop gneiss: No core: Yes	Low to possible	If RoW stays in gneiss on north side of ridge, then the ARD potential is low as showing is on south side. If mineralized rock is exposed, then the ARD is likely. Outcrop is too sparse to map mineralized trend at surface.
Misinchinka Gp.	Phyllite, schist	654-667	Schist: No Phyllite: Yes	Likely	RoW is on the north side of Missinka River. Surficial cover is variable and outcrops occur in logging road cuts. Phyllite likely to be greater potential acid generator than orthoquartzite schist.
Miette Fm	Shale	637.5-647	Yes	Likely	Surficial cover is thin, RoW would likely require rock grading and exposure of potentially acid generating rocks. Local rock has also been used in the past for rock surfacing for roads.
Palliser Fm.	Siltstone/shale	605.5-606	No	Low	Area will likely require extensive grading in rock.
Besa River Fm	Shale	601-605.5	Yes	Likely	Area will likely require extensive grading in rock that is likely to be acid generating.
Muskiki Fm	Sandstone	551.5-552.5	No	Low	Could not locate the type locality for reported pyritic sediments on the Smoky Gp Muskiki Fm. Associated sandstone formations of the Smoky Gp have a low ARD potential.
Kitimat and Hoult River Valleys	13 Samples	1080-1115	Hoult: Yes Others: No	Low	Outcrops in Kitimat and Hoult River valleys. Only one sample at the Hoult MINFILE was classified as PAG.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Based on the results of the GIS-based study and the site visits conducted in the summer of 2006, the following 9 sites are directly on the proposed alignment or within lithologies known to cross the alignment. These sites have a high potential to be a source of ARD based on laboratory determined ARD potential, the spatial extent of the unit, and the pipeline alignment. The sites listed on Table 8.1 are recommended for consideration for further investigation.

Table 8.1: Known Potential ARD Sites Along the RoW

Site	Approximate KP Location (Rev R)*	
	From	To
Kitimat Terminal (Proposed)	1172 (end of alignment)	includes all proposed Terminal facilities
Hoult MINFILE	1088	1089
Nimbus Ridge	1081	1082
Clore Ridge	1073	1079
Equity Silver and Foxy Creek	957	966
Misinchinka Gp	654	667
Miette Fm	637.5	647
Besa River Fm	601	605.5

* The KP locations for these sites have been extrapolated in relation to RoW and geology. The KP locations are not considered definitive boundaries.

This list is not considered comprehensive and is limited by the available geological knowledge along the proposed alignment. Further, much of the alignment is covered by surficial materials and outcrop is often sparse. Therefore, potential ARD sites may be uncovered during construction as acid generating geological materials are excavated or exposed. Conversely, additional investigative work may reduce the current list of potential ARD sites through more detailed assessments of the spatial extent and intensity of the ARD potential associated with the pipeline route. Further investigations of the depth of overburden in various areas may also result in some areas of potential ARD conditions being removed from the list due to deep overburden cover.

Table 8.2 summarizes locations where evidence for ARD is inconclusive, either due to lack of outcrop, inaccessibility to outcrop where it does exist, or uncertainty regarding the potential of a PAG unit to cross the alignment.

Table 8.2: Unknown Potential ARD Sites Along the RoW

Site	Approximate KP Location*	
	From	To
Wedeene MINFILE	1144	1144
R&F MINFILE	1121	1121
J MINFILE	1145	1145
Chisholm Lake MINFILE	1030	1030
Goldstream MINFILE	1026	1026
Silver Streak MINFILE	995	995

* The KP locations for these sites have been extrapolated in relation to the route and geological conditions. The KP locations are not considered definitive boundaries.

8.2 Recommendations

Based on the results of this investigation, the following recommendations are made:

- Further investigations should be conducted of potential ARD sites during detailed design and engineering. Detailed investigations may include geological mapping, higher density ARD sampling or shallow drilling.

- Where possible, efforts should be made to minimize the disturbance of bedrock associated with sites identified as having ARD potential.

It is possible that previously unknown ARD sites may be exposed during construction of the pipelines; mitigation and management plans should be developed to minimize any potential impacts from these sites.

9.0 LIMITATIONS AND CLOSURE

The findings and recommendations presented in this report are based on test results from samples collected during the field investigations and during office investigations using databases compiled by others as noted in this report. Further planning and work should be undertaken as part of detailed engineering, design and construction activities.

This report was prepared exclusively for Enbridge Pipelines Inc. and their agents, for specific application to the proposed project as described in the report. The data and recommendations provided herein should not be used for any other purpose, or by any other parties. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. The findings and recommendations of this report were prepared in accordance with generally accepted professional scientific principles and practice. No other warranty, expressed or implied, is given.

This report was prepared under the supervision of Steve Sibbick, P.Geo. Senior review was provided by Drum Cavers, P.Eng, P.Geo. If you have any questions or comments regarding this work, please do not hesitate to contact the undersigned.

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APPENDIX A

Analytical Laboratory Results

APPENDIX A
TABLE 1
ACID BASE ACCOUNTING RESULTS
ENBRIDGE GATEWAY PROJECT

Sample ID	Paste pH	CO2 (Wt.%)	CaCO3 Equivalent (Kg CaCO3/Tonne)	Total Sulphur (Wt.%)	Sulphate Sulphur (Wt.%)	Sulphide Sulphur* (Wt.%)	Maximum Potential Acidity** (Kg CaCO3/Tonne)	Neutralization Potential (Kg CaCO3/Tonne)	Net Neutralization Potential (Kg CaCO3/Tonne)	Neutralization Potential Rato***	Fizz Rating
Detection Limits	*0.1*	*0.01*	---	*0.02*	*0.01*	---	---	---	---	---	---
06-Alcan-001	9.3	0.61	13.9	0.18	<0.01	0.18	5.6	14.5	8.9	2.6	Moderate
06-Alcan-002	9.4	0.08	1.8	0.15	<0.01	0.15	4.7	11.8	7.1	2.5	None
06-Besa-001	6.5	0.54	12.3	2.02	0.02	2.00	62.5	9.9	-52.6	0.2	None
06-Besa-002	4.9	0.12	2.7	1.58	0.03	1.55	48.4	0.9	-47.6	0.0	None
06-Besa-003	8.6	38.89	883.9	0.02	<0.01	0.02	0.6	830.6	830.0	1329.0	Moderate
06-Besa-004	6.8	0.42	9.5	0.22	0.03	0.19	5.9	3.1	-2.8	0.5	None
06-Billy-001	9.0	0.07	1.6	0.43	0.01	0.42	13.1	6.3	-6.9	0.5	None
06-Bulk-001	8.8	0.71	16.1	<0.02	<0.01	<0.02	<0.6	16.3	16.3	54.2	silght
06-Clore-R-001	8.5	<0.01	<0.2	0.34	<0.01	0.34	10.6	14.3	3.6	1.3	None
06-Clore-R-002	6.6	<0.01	<0.2	0.30	0.01	0.29	9.1	9.8	0.7	1.1	None
06-EM-001	8.4	2.56	58.2	0.05	0.01	0.04	1.3	56.3	55.1	45.1	Moderate
06-EM-002	8.5	5.17	117.5	0.11	0.01	0.10	3.1	84.5	81.4	27.0	Moderate
06-EM-003	8.1	4.27	97.0	0.31	0.02	0.29	9.1	89.8	80.7	9.9	Moderate
06-EM-004	7.3	1.76	40.0	0.57	0.06	0.51	15.9	36.3	20.3	2.3	None
06-EM-005	3.7	0.09	2.0	2.52	0.11	2.41	75.3	-1.5	-76.8	0.0	None
06-EM-006	8.0	0.77	17.5	0.07	0.02	0.05	1.6	26.3	24.7	16.8	Moderate
06-EM-007	3.9	0.30	6.8	2.40	0.25	2.15	67.2	4.5	-62.7	0.1	None
06-Emw -001	7.6	<0.01	<0.2	0.03	<0.01	0.03	0.9	16.3	15.3	17.3	None
06-Emw -002	8.4	0.09	2.0	<0.02	<0.01	<0.02	<0.6	17.0	17.0	56.7	None
06-Endak -001	8.1	0.09	2.0	<0.02	0.01	<0.02	<0.6	-4.0	-4.0	-13.3	None
06-Endak -002	6.9	0.10	2.3	0.04	<0.01	0.04	1.3	13.8	12.5	11.0	None
06-Foxy -001	7.8	<0.01	<0.2	<0.02	<0.01	<0.02	<0.6	-15.3	-15.3	-50.8	None
06-Hansen -001	7.9	0.08	1.8	0.50	<0.01	0.50	15.6	4.3	-11.4	0.3	None
06-Hansen -002	8.7	1.78	40.5	1.69	<0.01	1.69	52.8	41.3	-11.5	0.8	Moderate
06-Hansen -003	9.0	0.01	0.2	<0.02	0.01	<0.02	<0.6	6.3	6.3	20.8	None
06-Hoe -001	9.3	0.14	3.2	0.08	<0.01	0.08	2.5	13.0	10.5	5.2	None
06-Hoe -002	9.1	<0.01	<0.2	0.05	<0.01	0.05	1.6	8.9	7.3	5.7	None
06-Hoult -003	8.4	0.07	1.6	0.13	<0.01	0.13	4.1	0.3	-3.8	0.1	None
06-Hoult -004	7.5	0.37	8.4	0.51	0.02	0.49	15.3	7.5	-7.8	0.5	None
06-Int -001	8.5	4.13	93.9	0.09	0.01	0.08	2.5	92.5	90.0	37.0	Moderate
06-Int -002	8.1	0.89	20.2	<0.02	0.01	<0.02	<0.6	28.8	28.8	95.8	Moderate
06-KLO-001	8.7	0.04	0.9	<0.02	<0.01	<0.02	<0.6	29.8	29.8	99.2	None
06-Miette-003	5.9	0.03	0.7	0.08	0.01	0.07	2.2	-0.1	-2.3	-0.1	None
06-Miette-004	3.0	<0.01	<0.2	23.15	0.13	23.02	719.4	-5.5	-724.9	0.0	None
06-Miss-001	7.8	0.02	0.5	0.15	0.01	0.14	4.4	3.8	-0.6	0.9	None
06-Miss-002	8.0	0.20	4.5	0.63	0.01	0.62	19.4	-6.4	-25.7	-0.3	None
06-Miss-003	7.4	<0.01	<0.2	0.03	<0.01	0.03	0.9	1.1	0.2	1.2	None
06-Miss-004	6.9	0.04	0.9	<0.02	<0.01	<0.02	<0.6	0.1	0.1	0.4	None
06-Miss-005	6.8	<0.01	<0.2	<0.02	0.01	<0.02	<0.6	1.5	1.5	5.0	None
06-Miss-006	7.6	<0.01	<0.2	0.02	0.01	0.01	0.3	2.5	2.2	8.0	None
06-Miss-007	5.5	<0.01	<0.2	0.05	0.01	0.04	1.3	-0.5	-1.7	-0.4	None
06-Mor-001	7.3	0.01	0.2	<0.02	<0.01	<0.02	<0.6	4.9	4.9	16.2	None
06-Muskn-001	7.8	1.47	33.4	0.04	<0.01	0.04	1.3	32.0	30.8	25.6	Slight
06-Muskn-002	8.0	0.09	2.0	<0.02	0.01	<0.02	<0.6	6.1	6.1	20.4	None

APPENDIX A
TABLE 1
ACID BASE ACCOUNTING RESULTS
ENBRIDGE GATEWAY PROJECT

Sample ID	Paste pH	CO2	CaCO3 Equivalent	Total Sulphur	Sulphate Sulphur	Sulphide Sulphur*	Maximum Potential Acidity**	Neutralization Potential	Net Neutralization Potential	Neutralization Potential Rato***	Fizz Rating
06-Rose-001	5.7	<0.01	<0.2	0.03	0.01	0.02	0.6	0.2	-0.4	0.4	None
06-Rose-002	8.2	3.07	69.8	0.50	0.02	0.48	15.0	73.3	58.3	4.9	Moderate
06-Rose-003	8.2	0.95	21.6	0.08	<0.01	0.08	2.5	18.8	16.3	7.5	Slight
06-Rose-004	6.1	<0.01	<0.2	0.05	0.01	0.04	1.3	-0.5	-1.7	-0.4	None
06-Rose-005	8.3	<0.01	<0.2	<0.02	<0.01	<0.02	<0.6	14.6	14.6	48.6	None
06-Smokey-001	6.9	<0.01	<0.2	<0.02	<0.01	<0.02	<0.6	0.4	0.4	1.2	None
06-Streak-001	8.4	2.35	53.4	<0.02	<0.01	<0.02	<0.6	59.1	59.1	197.0	Moderate
06-Telkwa-001	8.1	5.78	131.4	<0.02	<0.01	<0.02	<0.6	138.7	138.7	462.4	Moderate
06-Telkwa-002	8.6	2.65	60.2	<0.02	<0.01	<0.02	<0.6	61.3	61.3	204.4	Moderate
06-Term-001	9.0	<0.01	<0.2	0.48	0.02	0.46	14.4	11.6	-2.7	0.8	None
06-Term-002	9.5	<0.01	<0.2	<0.02	<0.01	<0.02	<0.6	3.9	3.9	12.9	None
06-Term-003	3.9	<0.01	<0.2	3.25	0.04	3.21	100.3	1.4	-98.9	0.0	None
Nimbus Ridge	7.5	0.20	4.5	0.44	0.02	0.42	13.1	14.6	1.5	1.1	Slight
Au qtz-vein sample	7.0	<0.01	<0.2	0.17	0.02	0.15	4.7	8.6	3.9	1.8	None
N-131	8.8	0.32	7.3	0.05	<0.01	0.05	1.6	10.0	8.5	6.4	None
N-17B	8.9	<0.01	<0.2	<0.02	0.01	<0.02	<0.6	7.2	7.2	24.0	None
N-17C	8.9	0.06	1.4	0.02	0.01	0.01	0.3	14.5	14.2	46.5	None
N-17H	8.8	0.99	22.5	0.06	0.01	0.05	1.6	31.5	29.9	20.1	Moderate
N-30C	9.0	0.02	0.5	<0.02	<0.01	<0.02	<0.6	14.8	14.8	49.2	None
N-301	7.6	0.01	0.2	0.11	<0.01	0.11	3.4	0.4	-3.1	0.1	None
N-30K	7.6	<0.01	<0.2	0.11	<0.01	0.11	3.4	-0.6	-4.1	-0.2	None
N-30L	8.7	<0.01	<0.2	0.11	<0.01	0.11	3.4	1.2	-2.2	0.4	None
N-30M	9.0	0.14	3.2	0.37	<0.01	0.37	11.6	2.7	-8.8	0.2	None
N-32E	9.1	8.85	201.1	0.42	<0.01	0.42	13.1	201.0	187.9	15.3	Moderate
N-33D	9.1	0.78	17.7	0.24	0.01	0.23	7.2	26.4	19.2	3.7	Moderate
N-90-2	8.5	0.13	3.0	0.30	0.01	0.29	9.1	17.0	7.9	1.9	None
N-9L-2	9.2	0.61	13.9	0.12	0.01	0.11	3.4	22.8	19.4	6.6	Slight
DC py sample	3.2	<0.01	<0.2	11.26	0.01	11.25	351.6	0.4	-351.2	0.0	None
06-Hoult-001	7.3	0.02	0.5	0.36	0.01	0.35	10.8	9.6	-1.2	0.9	None
06-Hoult-002	8.9	0.05	1.1	0.22	<0.01	0.22	6.9	2.4	-4.5	0.3	None
06-J-001	9.0	<0.01	<0.2	0.02	<0.01	0.02	0.6	6.3	5.6	10.0	None
06-J-002	8.4	<0.01	<0.2	0.17	0.02	0.15	4.7	8.6	3.9	1.8	None
06-J-003	9.2	0.07	1.6	0.36	0.06	0.30	9.3	27.0	17.7	2.9	None
06-Miette-001	9.1	2.92	66.4	0.46	0.04	0.42	13.1	68.4	55.3	5.2	None
06-Miette-002	4.0	<0.01	<0.2	5.88	0.12	5.76	179.9	-4.0	-183.9	0.0	None
Vizon Method Number	7160	LECO	Calculation	LECO	7410	Calculation	Calculation	7150	Calculation	Calculation	7150

APPENDIX A
TABLE 2
TRACE METALS ANALYSIS RESULTS
ENBRIDGE GATEWAY PROJECT

Sample ID	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Au	Th	Sr	Cd	Sb	Bi	V	Ca	P	La	Cr	Mg	Ba	Ti	B	Al	Na	K	W	Sc	Tl	Ga	Se	Hg*
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	%	ppm	%	ppm	%	%	%	ppm	ppm	ppm	ppm	ppm	ug/g
Detection Limits	*0.1*	*0.1*	*0.1*	*1*	*0.1*	*0.1*	*0.1*	*1*	*0.01*	*0.5*	*0.1*	*0.5*	*0.1*	*1*	*0.1*	*0.1*	*0.1*	*2*	*0.01*	*0.001*	*1*	*1*	*0.01*	*1*	*0.001*	*1*	*0.01*	*0.001*	*0.01*	*0.1*	*0.1*	*0.1*	*1*	*0.5*	*0.001*
06-Alcan-001	6.1	6.1	0.4	22	<0.1	3	4.8	275	1.23	<0.5	0.1	0.7	0.4	17	<0.1	<0.1	<0.1	8	0.64	0.02	1	86	0.38	29	0.037	1	0.65	0.036	0.08	0.1	1.6	<0.1	2	<0.5	<0.001
06-Alcan-002	4.1	47.8	1.3	61	<0.1	10.3	14.3	662	2.45	<0.5	<0.1	1.6	0.1	47	<0.1	0.2	<0.1	34	0.89	0.123	<1	73	1.74	9	0.108	1	1.82	0.022	0.03	0.1	2.6	<0.1	4	<0.5	<0.001
06-Besa-001	51.6	42.8	11.9	203	0.2	157	7.3	42	1.69	82.7	15.7	0.6	0.8	74	3.2	11.3	0.2	261	0.29	0.022	2	24	0.16	62	0.001	16	0.41	0.009	0.15	<0.1	2.8	0.5	1	13.9	0.20
06-Besa-002	58.5	41.4	9.2	182	0.2	161	7.3	26	1.23	32.9	15.7	1.9	1	84	2.8	8	0.2	317	0.09	0.022	4	26	0.05	96	0.001	16	0.42	0.007	0.16	<0.1	2.2	0.8	1	13.8	0.17
06-Besa-003	0.7	0.8	0.6	3	<0.1	1.5	0.1	89	0.11	0.5	0.4	1.2	0.1	336	0.1	0.1	<0.1	5	31.8	0.002	1	3	0.31	66	<0.001	2	0.02	0.004	0.01	<0.1	0.2	0.1	<1	<0.5	<0.001
06-Besa-004	26.8	27.1	8.7	54	0.1	50.6	2.2	9	0.57	8.8	5.3	2.3	2	30	0.4	1.7	0.1	162	0.15	0.032	1	19	0.04	556	0.001	8	0.4	0.007	0.2	<0.1	2.6	0.2	1	2.1	0.10
06-Billy-001	4.2	59.1	1.4	78	<0.1	3.7	7.2	907	2.57	0.9	0.1	2.8	0.7	6	0.1	0.1	0.1	26	0.25	0.044	1	60	1.64	57	0.077	1	1.78	0.024	0.2	0.1	1.7	0.1	4	<0.5	<0.001
06-Bulk-001	2.4	9.7	3.7	67	<0.1	2.7	3.1	451	1.12	1.9	0.3	0.8	1.9	36	0.1	<0.1	<0.1	15	0.63	0.037	6	33	0.06	101	0.003	3	0.26	0.03	0.1	<0.1	1.7	<0.1	1	<0.5	<0.001
06-Clore-R-001	9.5	38.2	15.8	65	<0.1	20.8	23.9	385	4.53	2.4	0.1	<0.5	0.3	120	<0.1	3	0.1	188	1.65	0.114	2	61	1.68	119	0.169	<1	3.35	0.309	0.84	0.1	4	0.2	9	<0.5	<0.001
06-Clore-R-002	3.5	51	0.9	40	<0.1	1.2	8.8	329	2.33	8	0.1	<0.5	0.6	15	<0.1	0.3	1.5	35	0.51	0.09	3	44	0.51	46	0.125	1	1.05	0.122	0.28	0.5	4.8	0.1	4	0.5	<0.001
06-EM-001	2.1	29.3	5.9	74	<0.1	6.1	19.8	694	4.14	5.6	1.2	0.7	3	225	0.1	0.2	<0.1	125	2.09	0.302	35	20	1.38	603	0.036	2	1.45	0.041	0.14	<0.1	5.9	<0.1	8	<0.5	0.34
06-EM-002	5.2	40.7	4.6	72	<0.1	29.1	18.2	1058	4.14	3.6	1.1	<0.5	2.8	161	0.2	0.6	0.1	109	2.5	0.219	29	63	1.54	514	0.067	2	0.9	0.078	0.21	<0.1	6.6	<0.1	5	<0.5	0.04
06-EM-003	3.1	43.4	6.8	64	<0.1	57.7	23.4	892	4.54	12.2	0.9	1.4	2.6	98	0.1	1	0.1	80	2.92	0.285	37	73	1.47	609	0.004	<1	1.23	0.021	0.19	<0.1	6.1	<0.1	5	<0.5	0.11
06-EM-004	4	41.9	5.7	192	<0.1	34.6	20.6	1587	3.97	4.9	1.8	0.7	2.2	68	0.2	0.3	<0.1	76	1.32	0.317	33	29	1.96	249	0.002	1	2.02	0.025	0.17	<0.1	2.5	<0.1	9	0.5	0.10
06-EM-005	5	19.5	8.2	12	<0.1	16.8	14.8	48	2.93	10	0.4	2.2	2.6	26	<0.1	0.5	0.1	7	0.1	0.127	34	26	0.08	26	0.001	1	0.36	0.017	0.23	<0.1	0.6	<0.1	1	2.3	0.11
06-EM-006	3.7	56	4.2	109	<0.1	26.3	16.4	1211	3.73	3.1	1.1	<0.5	1.6	87	0.2	0.7	0.1	61	1.25	0.318	41	35	1.08	994	0.003	1	1.49	0.026	0.21	<0.1	3	<0.1	7	<0.5	0.03
06-EM-007	7.5	49.2	14.6	21	<0.1	69.4	18.6	274	2.89	49.9	0.5	<0.5	3.2	41	0.1	0.5	0.1	17	0.68	0.249	38	16	0.12	38	0.001	3	0.61	0.014	0.23	<0.1	1	0.1	2	1.9	0.66
06-Emw -001	0.8	19.7	3.6	51	<0.1	26.5	12.4	487	3.44	0.8	0.9	<0.5	3	613	0.1	0.1	0.1	53	1.52	0.317	32	27	1.6	286	0.188	3	3.33	0.062	0.22	0.1	4.1	<0.1	7	0.5	0.01
06-Emw -002	3	17.2	2	52	<0.1	58.5	15.8	517	2.65	0.5	0.4	0.8	2.5	127	<0.1	0.1	<0.1	54	1.17	0.326	37	66	0.98	85	0.104	1	0.94	0.148	0.1	0.1	3.5	<0.1	2	<0.5	0.01
06-Endak -001	2.2	14.5	1.2	68	<0.1	89.8	27.4	798	4.33	0.9	0.4	<0.5	1.2	60	0.1	<0.1	<0.1	51	0.95	0.245	21	68	2.87	87	0.153	<1	0.42	0.09	0.09	0.1	6	<0.1	2	0.6	<0.001
06-Endak -002	0.7	17.9	4.3	49	<0.1	29.8	13.8	529	2.65	3.1	1	1.1	2.9	377	0.1	0.1	<0.1	72	1.56	0.105	28	29	1.15	397	0.253	1	3.42	0.086	0.89	0.1	5.9	0.5	8	0.6	<0.001
06-Foxy -001	1.7	22.9	3.1	51	<0.1	21.6	13.8	371	3.33	0.7	0.9	<0.5	3.1	82	0.1	0.1	0.1	95	0.84	0.212	23	63	0.63	152	0.174	<1	1.18	0.082	0.1	<0.1	2.7	0.1	4	<0.5	<0.001
06-Hansen -001	3.5	4.3	517.1	1487	0.9	1.8	1.5	1522	0.89	4	5.4	4.4	13.3	9	15.7	0.3	0.2	3	0.14	0.055	10	52	0.08	12	0.043	<1	0.43	0.013	0.19	1	0.3	0.1	2	0.5	<0.001
06-Hansen -002	6.7	1877.2	2.1	31	0.4	33	56.5	228	2.39	7.1	0.5	32	0.5	46	0.4	0.2	0.2	43	2.19	0.141	2	57	0.41	5	0.12	1	0.53	0.038	0.04	0.4	2.2	<0.1	2	0.8	<0.001
06-Hansen -003	3.5	50.3	3	50	<0.1	11.6	10.9	449	2.37	2.3	0.6	3.3	1.2	22	<0.1	0.1	<0.1	70	0.49	0.102	3	68	1.05	100	0.149	2	1.16	0.051	0.86	0.1	2.5	0.1	5	<0.5	<0.001
06-Hoe -001	2.7	34.3	4.7	54	<0.1	70.2	16.5	287	3.16	0.5	0.5	2.3	4	119	0.1	0.1	0.1	92	1.04	0.186	9	121	1.27	283	0.24	4	1.75	0.204	0.88	0.1	1.6	0.2	6	<0.5	<0.001
06-Hoe -002	2.8	46.8	3.7	41	<0.1	84.9	16.9	285	3.12	<0.5	0.4	0.7	2.8	111	0.1	0.1	0.1	83	1.02	0.184	9	130	1.3	190	0.183	1	1.64	0.185	0.44	0.1	1.7	0.1	6	<0.5	<0.001
06-Hoult -003	15.1	6.1	36.4	23	0.5	2.3	0.6	907	0.39	0.6	13.3	2.5	20.9	3	0.8	0.1	5.5	2	0.04	0.002	2	101	0.01	25	0.003	1	0.16	0.035	0.07	0.5	2.9	<0.1	1	0.5	<0.001
06-Hoult -004	18.8	4.1	9.2	5	<0.1	7.5	7.1	209	0.65	1.6	21	0.7	15.4	7	<0.1	0.1	0.7	1	0.25	0.002	2	59	0.04	4	0.001	1	0.12	0.016	0.05	0.4	1.6	<0.1	1	<0.5	<0.001
06-Int -001	1.6	54.5	5.5	80	<0.1	73.4	30.3	1592	5.71	2.6	0.3	5.4	1	86	0.2	0.1	<0.1	158	2.82	0.122	16	143	2.82	607	0.06	1	2.66	0.033	0.2	<0.1	10.9	0.2	10	<0.5	0.01
06-Int -002	1.1	63.2	0.9	59	<0.1	66.6	28.6	788	5.28	0.6	0.3	2.5	0.5	91	<0.1	<0.1	<0.1	164	2.3	0.102	5	125	2.91	151	0.124	<1	3.76	0.25	0.06	<0.1	5.7	<0.1	9	<0.5	<0.001
06-KLO-001	2.2	14	2.2	92	<0.1	7.4	14.2	737	4.11	0.6	0.6	<0.5	2.6	53	0.1	0.1	<0.1	171	1.04	0.224	26	15	1.14	42	0.129	<1	0.65	0.094	0.11	0.1	5	<0.1	4	<0.5	<0.001
06-Miette-003	2.3	30.9	12.3	99	<0.1	21.4	9.2	447	3.7	24.5	0.7	1.2	9	4	<0.1	1.7	0.5	15	0.02	0.031	16	33	0.82	18	0.001	<1	1.47	0.011	0.12	<0.1	1.6	<0.1	4	<0.5	0.01
06-Miette-004	7.3	103.8	42	49	<0.1	136.9	41.5	133	19.8	443.2	0.5	0.5	3.6	4	0.1	5.3	1.1	4	0.01	0.008	2	65	0.24	11	0.001	<1	0.48	0.007	0.06	<0.1	0.7	<0.1	1	5.4	0.02
06-Miss-001	0.8	19.6	2.6	99	<0.1	37.9	21.1	1077	4.21	3.6	0.7	1.1	15	6	<0.1	0.1	0.1	15	0.11	0.039	30	37	0.88	29	0.002	<1	2.1	0.014	0.1	<0.1	1.6	<0.1	6	<0.5	<0.001
06-Miss-002	1.4	32.6	23.4	99	<0.1	31.4	17.6	614	4.93	7.9	1.4	<0.5	17.2	12	<0.1	0.1	0.3	16	0.24	0.072	49	41	0.92	24	0.001	<1	2.23	0.011	0.11	<0.1	1.9	<0.1	6	<0.5	<0.001
06-Miss-003	7.5	2.1	4.6	14	<0.1	5.5	2.4	84	0.75	4.3	0.5	<0.5	7.1	4	<0.1	0.1	<0.1	1	0.04	0.027	11	97	0.05	9	<0.001	<1	0.18	0.011	0.03	<0.1	0.3	<0.1	1	<0.5	<0.001
06-Miss-004	6.9	3	6.9	22	<0.1	6.5	2.3	181	1.35	7.2	1	<0.5	15.9	3	<0.1	0.1	0.1	3	0.03	0.031	25	96	0.11	10	0.001	<1	0.31	0.011	0.04	<0.1	0.7	<0.1	1	<0.5	<0.001
06-Miss-005	2	32.7	23.6	111	<0.1	25.1	13.6	448	4.64	5.9	1.9	1.6	16.4	9	<0.1	0.1	0.3	10	0.1	0.057	37	40	0.61	32	0.002	<1	1.86	0.011	0.1	<0.1	1.7	<0.1	5	<0.5	0.01
06-Miss-006	0.9	37.4	22.1	112	<0.1	33.2	28.3	824	4.63	15.1	0.9	<0.5	13.6	13	<0.1	0.1	0.3	10	0.06	0.034	58	29	0.76	42	0.001	<1	2.11	0.006	0.14	<0.1	1.4	<0.1	5	<0.5	<0.001
06-Miss-007	4.6	9.1	9.2	47	<0.1	11.3	2.1	378	2.69	3.4	0.3	<0.5	10.7	6	<0.1	0.9	0.2	19	0.02	0.034	16	26	1	20	0.001	1	1.46	0.008	0.14	<0.1	1.1	<0.1	4	<0.5	0.01
06-Mor-001	3.6	20.6	2.4	56	<0.1	8.2	10.6	551	2.43	4.7	0.6	1.5	1.2	14	0.1	0.4	<0.1	49	0.55	0.064	5	57	0.96	61	0.153	<1	1.23	0.015	0.09	0.1	5.4	0.1	3	<0.5	<0.001
06-Muskn-001	3.1	11.7	8.7	75	0.1	20.6	5.1	70	1.19	7	0.7	0.8	4	20	0.1	0.5	0.1	30	0.84	0.071	7	49	0.6	147	0.002	5	0.69	0.007	0.17	<0.1	2.2	0.1	2	0.5	0.04
06-Muskn-002	3.2	18.7	11.5	59	<0.1	25.1	13.3	694	3.23	2	0.4	<0.5	8.7	9	<0.1	0.2	0.2	24	0.34	0.055	22	59	0.88	65	0.15	1	1.42	0.006	0.17	0.1	1.7	<0.1	4	0.5	<0.001
06-Rose-001	1.2	11.8	2.8	51	<0.1	5.5	1.6	288	2.94	168	0.1	<0.5	1.2	8	<0.1	2.2	0.1	20	0.06	0.048	8	34	0.9	38	0.001	<1	1.82	0.016	0.14	<0.1	1.8	<0.1	4	0.5	0.01
06-Rose-002	2.3	37.9	7.2	89	<0.1	106.1	27.3	931	5.34	2.1	0.3	<0.5	0.7	148	0.1	0.2	0.1	146	3.21	0.246	22	166	3.25	322	0.078	<1	3.32	0.098	0.03	<0.1	9.3	<0.1	11	<0.5	<0.001
06-Rose-003	3.8	6	3.1	64	<0.1	36.7	9.3	361	3.74	5	0.1	<0.5	1.7	42	<0.1	0.2	<0.1	35	0.7	0.029	11	96	0.7	50	0.002	2	1.53	0.012	0.14	<0.1	3.7	<0.1	4	0.5	0.01
06-Rose-004	1.5	13.1	3.8	57	<0.1	8.6	2.5	215	3.6	12	0.1	<0.5	1	8	<0.1	0.3	0.1	21	0.04	0.054	11	37	0.91	45	0.001	1	1.86	0.012	0.14	<0.1	1.7	<0.1	4	0.7	<0.001
06-Rose-005	1.5	53.9	0.8	63	<0.1	75.3	23.6	664	4.68	<0.5	0.3	<0.5	0.8	90	0.1	<0.1	<0.1	120	1.19	0.238	15	102	2.29	33	0.19	<1	2.3	0.124	0.04	<0.1	1.5	<0.1	7	<0.5	<0.001
06-Smokey-001	6.8	6.3	5	24	<0.1	10.6	2.6	32	0.49	2.8	0.3	0.6	1.9	7	0.1	0.2	0.1	12	0.05	0.005	7	96	0.1	53	0.001	<1	0.36	0.004	0.08	<0.1	1.1	<0.1	1	<0.5	0.01
06-Streak-001	1	56.1	0.9	54	<0.1	113	27.7	1158	5.34	<0.5	0.2	0.8	0.5	104	<0.1	<0.1	<0.1	121	2.85	0.143	11	138	4.23	111	0.163	6	3.41	0.154	0.03	<0.1	13.9	<0.1	10	<0.5	<0.001
06-Telkwa-001	1.5	36.6	8	125	<0.1	9.9	16.9	1407	5.86	18	0.2	1.1	0.6	46	2.3	0.3	<0.1	246	5.01	0.069	2	26	0.36	226	0.003	5	0.69	0.004	0.02	0.1	20.6	<0.1	1	<0.5	0.04
06-Telkwa-002	2	11.4	4	82	<0.1	9.4	27.1	1118	7.08	13.1	0.3	0.7	1	39	0.1	1.1	<0.1	151	1.7	0.13	4	35	0.73	74	0.081	6	0.55	0.023	0.04	0.4	21.4	<0.1	3	<0.5	<0.001
06-Term-001	1.7	84.9	0.7	23	<0.1	8.3	29.9	269	6.24	0.5	0.1	1.6	<0.1	251	<0.1	<0.1	<0.1	342	3.35	0.036	<1	21	0.65	17	0.119	<1	4.86	0.207	0.05	<0.1	6.3	0.2	9	<0.5	<0.001
06-Term-002	5.4	3.3	4.4	19	<0.1	2.9	1.8	117	0.67	<0.5	8.7	1.8	11.4	10	<0.1	<0.1	<0.1	14	0.19	0.011	10	81	0.14	15	0.028	<1	0.34	0.037	0.08	0.1	1.5	0.1	2	<0.5	<0.001
06-Term-003	9.4	426.2	1	23	0.1	7.8	468.7	210	5.43	4.9	3.5	2.2	0.7	33	<0.1	0.1	0.7	81	0.54	0.005	1	78	0.41	52	0.07	<1	1.23	0.073	0.12	<0.1	3.5	0.1	4	1.4	<0.001
Nimbus Ridge	4	55.9	16.4	164	<0.1	15.2	13.8	859	3.24	1.5	0.1	3.3	0.3	37	0.3	0.1	0.1	56	0.92	0.109	2	65	1.31	56	0.141	<1	1.56	0.018	0.21	0.2	2.8	<0.1	4	0.6	<0.001
Au qtz-vein sample	3.6	683.2	7.4	170	2	38.3	24.9	1374	4.28	1.3	0.1	4.4	0.2	82	0.2	0.3	0.1	84	1.07	0.127	2	59	2.54	21	0.21	<1	2.98	0.011	0.11	0.1	4.2	<0.1	7	0.7	<0.001
N-131	4.7	3.8	2.8	54	<0.1	2.4	4.7	348	1.82	0.7	2.3	0.6	5.6	21	<0.1	<0.1	0.1	44	0.49	0.079	8	65	0.52	353	0.142	2	0.6	0.035	0.42	0.2	1.6	0.2	4	0.6	<0.001
N-17B	3.1	29.7	0.6	26	<0.1	13.7	10	229	3.31	1.5	0.2	0.5	0.2	51	<0.1	0.1	0.9	93	0.65	0.06	1	67	0.63	30	0.147	1	1.2	0.15	0.38	0.2	2.9	0.1	4	<0.5	<0.001
N-17C	12	66.2	2	129	0.2	12.7	24.4	708	6.21	0.8	0.2	<0.5	0.4	64	<0.1	0.1	0.1	185	1.16	0.193	2	41	1.54	27	0.198	2	2.03	0.087	0.04	0.4	5.2	<0.1	8	<0.5	<0.001
N-17H	2.1	29.6	1.6	58	<0.1	78.9	24.2	525	5	0.5	0.2	<0.5	0.6	95	0.1	<0.1	<0.1	128	2.21	0.187	11	126	2.18	144	0.215	<1	2.79	0.282	0.3	0.1	2.8	0.1	9	<0.5	<0.001
N-30C	3.5	59.2	10.6	55	<0.1	41.4	17.2	337	4.17	<0.5	0.3	<0.5	1.8	180	<0.1	1	0.2	106	1.24	0.273	16	63	1.16	187	0.194	<1	1.6	0.177	0.31	0.1	1.6	0.1	7	<0.5	<0.001
N-301	24.5	5.5	12.3	11	<0.1	1.5	0.4	421	0.31	0.5	25.8	<0.5	18.7	2	0.1	<0.1	0.4	1	0.03	0.001	2	66	0.01	7	0.002	<1	0.1	0.02	0.05	0.4	1.9	<0.1	1	<0.5	<0.001
N-30K	10.9	3.1	16	21	0.2	2.5	0.6	275	0.32	<0.5	15.5	1	18.9	2	0.3	<0.1	2.7	2	0.05	0.003	2	71	0.03	4	0.005	<1	0.15	0.02	0.04	0.4	1.5	0.1	1	<0.5	<0.001
N-30L	14	3.8	17.2	11	0.2	2.4	0.8	418	0.36	0.6	18.3	0.8	19.5	3	0.2	<0.1	1.9	1	0.04	0.001	3	92	0.01	10	0.003	1	0.13	0.033	0.07	0.7	3.2	<0.1	1	<0.5	<0.001
N-30M	7.1	3.6	23.8	11	0.4	1.4	0.3	459	0.42	1.3	24.4	1.1	18.8	2	0.2	<0.1	8.7	1	0.1	0.001	2	77	0.01	2	0.001	<1	0.11	0.025	0.05	0.4	2	<0.1	1	<0.5	<0.001
N-32E	1.4	8.6	4.1	67	<0.1	20.5	15.6	1515	3.26	<0.5	0.2	<0.5	0.5	255	0.2	0.1	0.1	39	8.22	0.06	2	44	1.36	55	0.085	<1	1.49	0.012	0.16	0.1	3	<0.1	4	<0.5	<0.001
N-33D	2.3	37	1.5	208	<0.1	10	23.4	929	4.75	2.4	0.4	1.2	0.8	41	<0.1	0.2	0.1	102	1.46	0.249	3	28	1.54	139	0.181	1	1.85	0.016	0.75	0.1	3.4	0.1	7	<0.5	<0.001
N-90-2	3.5	71.7	9.5	72	0.2	41.8	26.1	375	4.1	1.7	0.4	<0.5	1.2	79	0.2	0.1	0.3	96	1.07	0.252	13	92	1.15	231	0.204	<1	1.22	0.104	0.28	0.1	1.6	0.1	6	<0.5	<0.001
N-9L-2	2.9	29.2	6.1	69	<0.1	77.9	17.2	356	3.24	1.3	0.7	<0.5	4.1	164	0.1	0.1	0.2	85	1.32	0.182	10	106	1.4	589	0.271	1	1.87	0.208	1.03	<0.1	1.9	0.3	7	<0.5	0.08
DC py sample	5.6	134.4	28	78	<0.1	101.7	25.2	342	13.01	353.6	0.9	<0.5	6.8	6	0.3	3.4	0.4	9	0.05	0.03	4	66	0.5	22	0.004	<1	0.96	0.008	0.14	<0.1	1.1	<0.1	3	5.4	0.01
06-Hoult-001	58.9	136.2	2.2	126	0.3	3	11.8	1041	4.61	2	0.4	1.6	0.5	15	0.1	<.1	1.3	137	0.8	0.195	4	48	1.21	224	0.295	2	1.45	0.079	1.13	2.3	10.4	0.9	7	0.7	na
06-Hoult-002	19.2	8.9	13.7	9	<.1	2.9	2.7	476	0.5	1.2	14	1.1	19.4	2	0.2	<.1	1	2	0.07	0.002	2	125	0.02	10	0.003	<1	0.18	0.045	0.1	0.4	2.5	<.1	1	<.5	na
06-J-001	2.9	51.9	4.2	33	<.1	31.1	12.4	332	2.4	<.5	0.1	<.5	0.3	69	0.1	<.1	<.1	82	1.26	0.083	1	78	1.21	49	0.15	2	1.87	0.193	0.12	0.1	4.5	<.1	5	<.5	na
06-J-002	5	76.1	0.9	32	<.1	9.9	17.4	282	1.91	<.5	0.1	0.6	0.5	30	<.1	<.1	0.1	61	0.8	0.058	1	69	0.87	133	0.129	1	1.31	0.099	0.35	0.1	3.4	<.1	4	<.5	na
06-J-003	1.8	81.3	4	111	<.1	50.8	24.8	1007	6.54	<.5	0.2	0.7	0.8	358	0.1	<.1	<.1	148	2.97	0.358	30	74	1.94	43	0.3	5	2.59	0.296	0.08	<.1	6.8	<.1	13	<.5	na
06-Miette-001	3.6	49.3	27.9	101	<.1	36.7	23.6	808	4.97	8.7	1.5	1.4	11.6	113	0.5	0.1	0.4	28	2.45	0.069	32	56	1.09	48	0.012	1	1.94	0.009	0.28	0.1	2.8	0.1	6	1.3	na
06-Miette-002	6.4	66.2	38.1	46	<.1	72.5	17	43	7.13	246	0.9	<.5	5.8	7	<.1	3.2	0.7	10	0.01	0.011	5	70	0.29	15	0.001	1	0.74	0.025	0.16	<.1	1.3	<.1	3	3.1	na
QA/QC																																			
RE 06-Clore-R-002	3.1	52.3	1	40	<0.1	0.9	8.6	324	2.29	7.6	0.1	0.7	0.6	15	<0.1	0.2	3.5	35	0.49	0.088	3	42	0.5	43	0.122	1	1.01	0.126	0.25	0.5	4.4	0.2	4	<0.5	-
RE 06-Endak -001	2.2	14.3	1.6	69	<0.1	92.2	27.9	819	4.34	1.6	0.4	<0.5	1.2	57	0.1	<0.1	<0.1	52	0.96	0.245	21	68	2.96	84	0.154	1	0.42	0.097	0.08	0.1	5.7	<0.1	2	<0.5	-
RE 06-Int -001	2.3	54.5	5.2	83	<0.1	73.8	31.9	1571	5.73	2.4	0.2	0.7	1	90	0.1	0.1	<0.1	157	2.83	0.154	16	154	2.82	605	0.062	1	2.62	0.031	0.19	<0.1	11.1	0.1	10	<0.5	-
RE 06-Miss-006	0.9	34.3	21.4	109	<0.1	32.4	25.9	792	4.54	11.8	0.9	<0.5	13.6	13	<0.1	0.1	0.3	9	0.05	0.03	55	28	0.75	40	0.001	<1	2.02	0.006	0.12	<0.1	1.2	<0.1	5	<0.5	-

APPENDIX A
TABLE 2
TRACE METALS ANALYSIS RESULTS
ENBRIDGE GATEWAY PROJECT

Sample ID	Mo ppm	Cu ppm	Pb ppm	Zn ppm	Ag ppm	Ni ppm	Co ppm	Mn ppm	Fe %	As ppm	U ppm	Au ppb	Th ppm	Sr ppm	Cd ppm	Sb ppm	Bi ppm	V ppm	Ca %	P %	La ppm	Cr ppm	Mg %	Ba ppm	Ti %	B ppm	Al %	Na %	K %	W ppm	Sc ppm	Tl ppm	Ga ppm	Se ppm	Hg* ug/g
RE 06-Smokey-001	6.6	6.5	4.9	25	<0.1	10.3	2.6	31	0.48	2.7	0.3	0.8	1.9	7	<0.1	0.2	0.1	12	0.04	0.005	6	92	0.1	51	0.001	3	0.35	0.004	0.08	<0.1	0.9	<0.1	1	<0.5	-
RE Unidentified(Pail Sample)	5.5	132.5	26.2	74	<0.1	102.8	22.6	336	12.82	352.4	0.8	<0.5	6.3	5	0.3	3.3	0.4	9	0.05	0.027	4	62	0.48	23	0.003	<1	0.95	0.009	0.15	0.1	1	0.1	3	5.2	-
STANDARD DS7	19.9	103.7	69.8	403	0.7	54.5	9.5	614	2.35	48.1	4.9	67.5	4.5	69	6.3	5.6	4.5	84	0.91	0.076	12	158	1.03	364	0.121	39	0.95	0.072	0.44	3.8	2.5	4.1	5	3.5	-
STANDARD DS7	20.4	101.7	56.7	402	0.9	53	8.3	617	2.34	47.9	4.8	63.1	4.4	69	6.3	6	4.4	81	0.92	0.077	12	153	1.03	364	0.107	39	0.96	0.075	0.44	3.2	2.4	4	4	3.5	-
STANDARD DS7	20.4	109.2	66.4	400	0.9	54.4	9.4	630	2.38	48.1	4.8	68.2	4.3	66	6.2	5	4.4	85	0.92	0.077	11	157	1.05	365	0.119	38	0.97	0.075	0.43	3.7	2.5	4.1	5	3.6	-
RE KN06-02-554	6.6	13.6	7.4	76	<0.1	19.8	7.8	246	2.33	2.1	0.6	<0.5	3.9	68	0.2	0.1	0.1	20	1.13	0.093	4	101	0.73	259	0.001	10	0.8	0.039	0.37	<0.1	2.8	<.1	2	0.5	2.13
STANDARD DS6/CSC	11.5	123.8	29.3	141	0.3	24.8	10.8	693	2.82	21.4	6.6	46.4	3	40	6.3	3.5	5	55	0.85	0.081	14	188	0.57	166	0.082	16	1.91	0.076	0.16	3.4	3.3	1.7	6	4.4	3.10
RE 06-Miette-002	6.9	64.6	41.1	48	<.1	74.9	17.6	44	7.3	262.9	0.9	1.7	5.9	8	0.1	3.6	0.7	10	0.02	0.012	5	74	0.3	13	0.001	1	0.76	0.026	0.18	<.1	1.3	<.1	3	3.2	
STANDARD DS7	20.8	106.8	70.8	409	0.9	55.7	9.7	624	2.39	47.6	5	47	4.4	73	6.3	5.3	4.5	84	0.93	0.081	13	172	1.05	370	0.126	39	0.97	0.079	0.45	3.8	2.6	4.1	4	3.3	

All samples are surface grab samples.
Metals analyzed using aqua regia digestion with ICP-MS finish.
*Mercury analyzed by cold vapour analysis with atomic absorption (CVAA)

APPENDIX A
TABLE 3
RESULTS OF WHOLE ROCK ANALYSIS BY XRF
ENBRIDGE GATEWAY PROJECT

Sample ID	SiO2 %	TiO2 %	Al2O3 %	Fe2O3 %	MnO %	MgO %	CaO %	Na2O %	K2O %	P205 %	Ba(F) %	LOI %	Total %
Detection Limits	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	-	-
06-Alcan-001	73.99	0.26	12.45	2.80	0.05	0.73	2.33	4.36	0.94	0.11	0.03	1.58	99.63
06-Alcan-002	61.20	0.64	14.71	6.92	0.16	3.27	7.25	2.59	0.56	0.25	0.02	2.29	99.86
06-Besa-001	77.14	0.31	6.68	2.99	0.01	0.54	0.46	0.14	1.27	0.11	0.07	9.61	99.33
06-Besa-002	76.70	0.31	7.32	2.37	0.01	0.40	0.13	0.21	1.42	0.12	0.09	10.51	99.59
06-Besa-003	1.05	0.02	0.37	0.20	0.01	0.62	54.44	0.01	0.03	0.05	0.01	43.36	100.17
06-Besa-004	78.94	0.34	8.16	1.41	0.01	0.99	0.28	0.10	1.80	0.08	0.14	7.63	99.88
06-Billy-001	66.56	0.35	15.26	4.84	0.12	3.37	1.59	2.84	2.01	0.10	0.08	2.65	99.77
06-Bulk-001	69.94	0.31	15.65	2.05	0.05	0.11	1.12	4.56	2.73	0.13	0.11	2.83	99.59
06-Clore-R-001	47.13	1.17	17.96	11.43	0.26	7.27	8.70	3.06	1.33	0.27	0.02	1.28	99.88
06-Clore-R-002	70.00	0.74	13.77	4.25	0.12	1.21	3.78	4.26	0.55	0.21	0.01	0.80	99.70
06-EM-001	54.75	1.27	16.36	7.22	0.09	2.55	4.57	3.97	2.57	0.70	0.16	5.29	99.50
06-EM-002	53.15	1.12	16.33	6.45	0.12	2.89	6.41	3.48	2.55	0.59	0.18	6.41	99.68
06-EM-003	52.69	1.16	15.82	7.24	0.11	2.73	5.13	2.40	3.01	0.60	0.19	8.11	99.19
06-EM-004	54.55	1.27	18.51	6.36	0.19	3.63	2.07	4.74	1.87	0.77	0.12	5.34	99.42
06-EM-005	61.36	1.33	19.06	5.13	0.01	0.78	0.19	1.69	4.36	0.38	0.17	5.53	99.99
06-EM-006	56.41	1.28	18.60	6.34	0.15	2.14	2.09	5.10	2.25	0.74	0.14	4.53	99.77
06-EM-007	62.67	1.23	15.97	5.11	0.04	0.65	1.04	2.15	3.21	0.60	0.15	6.27	99.09
06-Emw -001	48.09	1.30	14.49	8.71	0.11	5.41	5.55	1.86	2.27	0.83	0.13	10.63	99.38
06-Emw -002	52.42	1.33	15.97	9.14	0.14	4.14	7.20	3.44	2.29	0.83	0.13	2.92	99.95
06-Endak -001	51.16	1.70	15.37	10.48	0.15	5.75	7.72	2.69	1.85	0.88	0.10	1.30	99.15
06-Endak -002	50.62	1.09	13.97	7.03	0.10	3.47	5.32	1.29	2.11	0.54	0.10	13.65	99.29
06-Foxy -001	52.82	1.10	15.86	8.27	0.12	4.00	6.18	3.48	1.22	0.57	0.11	5.98	99.71
06-Hansen -001	74.14	0.16	13.32	1.72	0.22	0.25	0.30	1.04	6.76	0.12	0.07	1.56	99.66
06-Hansen -002	51.53	1.00	14.63	8.43	0.10	4.07	11.69	4.64	0.71	0.30	0.03	1.52	98.65
06-Hansen -003	62.22	0.57	16.66	5.12	0.09	2.41	4.41	4.32	2.78	0.29	0.12	0.69	99.68
06-Hoe -001	57.45	1.04	15.64	7.03	0.11	5.12	6.29	3.64	2.06	0.43	0.11	0.72	99.64
06-Hoe -002	53.66	1.05	16.03	7.90	0.12	6.32	6.84	3.50	2.35	0.42	0.11	1.17	99.47
06-Hoult -003	76.20	0.05	13.08	0.68	0.13	0.01	0.39	3.98	4.43	0.02	0.01	0.77	99.75
06-Hoult -004	76.07	0.04	12.63	1.07	0.02	0.03	0.44	2.94	4.65	0.01	0.03	1.89	99.82
06-Int -001	50.56	0.92	15.60	8.74	0.18	5.01	4.98	3.47	1.48	0.33	0.08	8.19	99.54
06-Int -002	48.88	0.83	16.29	10.36	0.16	6.89	8.10	2.99	0.72	0.22	0.05	4.29	99.78
06-KLO-001	54.38	1.45	16.50	8.49	0.13	2.92	5.55	4.22	2.59	0.76	0.15	2.53	99.67
06-Miette-003	61.34	0.84	19.92	5.70	0.05	1.73	0.07	1.01	4.13	0.12	0.06	4.80	99.77
06-Miette-004	44.71	0.30	5.67	30.37	0.01	0.38	0.06	0.03	1.14	0.04	0.02	16.35	99.08
06-Miss-001	58.79	0.96	21.14	7.78	0.14	1.80	0.20	1.10	4.05	0.12	0.10	3.65	99.83
06-Miss-002	56.75	1.08	21.60	8.51	0.08	1.93	0.42	1.19	4.06	0.21	0.07	3.91	99.81

APPENDIX A
TABLE 3
RESULTS OF WHOLE ROCK ANALYSIS BY XRF
ENBRIDGE GATEWAY PROJECT

Sample ID	SiO2 %	TiO2 %	Al2O3 %	Fe2O3 %	MnO %	MgO %	CaO %	Na2O %	K2O %	P205 %	Ba(F) %	LOI %	Total %
06-Miss-003	91.04	0.19	4.35	1.20	0.01	0.01	0.08	1.33	0.46	0.05	0.01	0.71	99.44
06-Miss-004	87.67	0.39	5.69	2.11	0.01	0.13	0.06	1.75	0.59	0.06	0.01	0.98	99.45
06-Miss-005	58.14	0.97	22.09	7.46	0.05	1.24	0.14	0.69	4.70	0.15	0.09	4.11	99.83
06-Miss-006	58.37	0.97	21.41	7.76	0.10	1.89	0.09	0.60	4.89	0.08	0.12	3.68	99.96
06-Miss-007	58.50	0.95	21.01	4.59	0.04	2.51	0.06	1.53	4.53	0.08	0.06	5.88	99.74
06-Mor-001	64.60	0.62	15.03	6.23	0.12	1.96	4.64	2.38	1.60	0.20	0.08	2.45	99.91
06-Muskn-001	78.91	0.44	7.74	2.20	0.00	1.31	1.30	1.55	1.70	0.17	0.07	4.58	99.97
06-Muskn-002	68.87	0.96	13.03	6.65	0.10	2.43	0.69	1.41	3.05	0.15	0.07	2.58	99.99
06-Rose-001	64.06	0.87	18.55	4.78	0.03	1.70	0.15	0.80	3.07	0.14	0.08	5.66	99.89
06-Rose-002	51.68	1.10	15.35	7.96	0.11	5.64	6.69	2.94	0.27	0.53	0.11	6.92	99.30
06-Rose-003	73.70	0.41	10.49	6.02	0.04	1.41	1.08	1.79	1.39	0.07	0.04	3.39	99.83
06-Rose-004	63.26	0.83	18.06	5.67	0.02	1.72	0.12	1.63	3.28	0.12	0.09	5.16	99.96
06-Rose-005	49.50	1.38	16.80	9.03	0.14	6.73	7.75	3.73	1.21	0.57	0.07	2.98	99.89
06-Smokey-001	90.88	0.26	4.40	0.95	0.01	0.19	0.10	0.11	0.77	0.01	0.03	1.88	99.59
06-Streak-001	47.13	1.24	16.85	8.58	0.17	7.86	6.70	3.78	0.41	0.32	0.04	6.86	99.94
06-Telkwa-001	50.78	0.80	15.18	9.07	0.17	0.61	8.04	1.03	0.14	0.16	0.03	13.93	99.94
06-Telkwa-002	35.93	1.55	23.18	18.06	0.17	1.80	4.36	7.00	0.60	0.48	0.05	6.06	99.24
06-Term-001	39.66	1.55	16.24	19.71	0.19	7.41	12.37	1.06	0.43	0.10	0.01	1.00	99.73
06-Term-002	74.17	0.13	14.25	1.15	0.01	0.19	1.51	4.14	3.54	0.03	0.07	0.54	99.73
06-Term-003	59.72	0.66	10.28	16.66	0.08	2.40	4.21	1.02	0.68	0.02	0.04	3.49	99.26
Nimbus Ridge	63.37	0.83	13.85	7.24	0.14	2.47	5.08	3.35	0.77	0.25	0.03	2.44	99.82
Au qtz-vein sample	50.23	1.14	16.92	11.01	0.26	4.59	9.56	2.31	0.17	0.31	0.01	3.40	99.91
N-131	67.79	0.54	15.67	3.10	0.05	1.08	3.10	4.11	3.02	0.18	0.13	0.82	99.59
N-17B	59.18	0.64	16.66	7.96	0.08	3.09	6.55	3.07	1.58	0.15	0.04	0.71	99.71
N-17C	55.36	1.58	14.51	11.89	0.16	4.31	6.73	2.21	1.02	0.45	0.07	1.66	99.95
N-17H	51.10	1.37	16.07	9.64	0.15	6.14	7.11	3.25	1.65	0.49	0.10	2.77	99.84
N-30C	53.51	1.24	16.34	8.74	0.12	5.07	7.08	3.13	2.27	0.66	0.17	1.21	99.54
N-301	77.16	0.04	12.64	0.53	0.11	0.01	0.42	3.52	4.81	0.01	0.01	0.52	99.78
N-30K	75.91	0.06	13.32	0.68	0.11	0.07	0.42	3.92	4.53	0.01	0.01	0.76	99.80
N-30L	75.81	0.06	13.49	0.64	0.06	0.01	0.39	4.03	4.63	0.01	0.01	0.64	99.78
N-30M	75.12	0.06	13.55	0.78	0.12	0.01	0.52	3.98	4.49	0.01	0.01	0.80	99.45
N-32E	45.97	0.57	14.66	5.91	0.19	3.02	12.01	3.14	2.42	0.14	0.07	10.94	99.04
N-33D	54.21	1.36	16.30	9.88	0.22	2.77	6.66	3.78	1.41	0.61	0.04	2.18	99.42
N-90-2	55.79	1.33	15.90	8.14	0.11	4.47	5.92	3.60	2.02	0.62	0.14	1.63	99.67
N-9L-2	55.03	1.07	15.69	7.39	0.11	5.69	6.97	3.20	2.25	0.45	0.11	1.50	99.46
DC py sample	55.99	0.63	10.19	18.49	0.04	1.19	0.14	0.86	2.18	0.09	0.03	9.80	99.63
06-HOULT-001	60.00	1.21	14.76	8.14	0.17	2.83	4.98	4.14	1.91	0.43	0.07	0.95	99.59

APPENDIX A
TABLE 3
RESULTS OF WHOLE ROCK ANALYSIS BY XRF
ENBRIDGE GATEWAY PROJECT

Sample ID	SiO2 %	TiO2 %	Al2O3 %	Fe2O3 %	MnO %	MgO %	CaO %	Na2O %	K2O %	P205 %	Ba(F) %	LOI %	Total %
06-HOULT-002	76.36	0.06	12.62	0.83	0.06	0.03	0.35	3.93	4.58	0.01	0.01	0.66	99.49
06-J-001	52.03	0.87	16.83	9.25	0.16	6.24	8.61	2.97	1.03	0.18	0.03	1.54	99.75
06-J-002	61.06	0.49	15.31	6.43	0.12	3.54	7.06	3.33	1.07	0.13	0.04	1.21	99.78
06-J-003	45.68	2.10	15.46	12.05	0.15	6.12	8.26	4.44	1.30	1.08	0.05	2.57	99.27
06-MIETTE-001	58.03	1.14	14.68	8.21	0.09	2.71	3.96	1.46	3.40	0.15	0.05	4.96	98.85
06-MIETTE-002	57.52	0.74	15.92	10.24	0.01	0.82	0.04	1.34	3.37	0.05	0.05	9.56	99.65
QA/QC													
STD: SY-4	49.75	0.28	20.75	6.18	0.10	0.52	8.03	7.17	1.61	0.12	0.03	4.80	99.35
STD: SY-4	49.77	0.28	20.68	6.11	0.10	0.53	8.07	7.08	1.66	0.13	0.03	4.63	99.08
STD: SY-4	49.77	0.28	20.68	6.11	0.10	0.53	8.07	7.08	1.66	0.13	0.03	4.63	99.08

ANALYTICAL METHODS
Other elements by Li borate fusion/XRF. Where no FeO value shown "Fe2O3" is total Fe as Fe2O3.

APPENDIX B

Field Investigation Site Descriptions

Note: All references to Kilometer Posts (KP) and the pipeline alignment in this appendix are with respect to the Revision H pipeline alignment. In the main body of the report, all references to the pipeline alignment and KPs have been updated to the Revision R pipeline alignment.

Site Name: Kitimat Terminal Area
NTS: 103H 15
UTM: Zone 9 518740E 5977802N
Photos 1 and 2
Physiographic Area: Kitimat Ranges
Reason for Concern: Large volumes of rock to be removed for terminal construction

Regional Geology: Coast Plutonic Complex, Hazelton Group
The Coast Plutonic Complex is a narrow zone of dominantly plutonic rocks, mixed with subordinate metamorphic rocks that extend 1,610 km south from the Yukon Territory, to southern British Columbia. It forms a collisional suture that separates the Intermontane Superterrane to the east from the Insular Superterrane to the west. Magmatism was synchronous with accretion, deformation and metamorphism of these terranes. In texture, the plutons range from intensely foliated to massive, with incorporated slivers and pendants of metamorphosed country rock. Episodic magmatic events spanned Jurassic to Tertiary (185-50 Ma) times. Early Jurassic plutons may be the intrusive equivalents of Lower Jurassic Hazelton Group volcanic rocks, particularly the Telkwa Formation. The plutons vary in composition from gabbro to granite, with quartz diorite comprising 40% of the intrusive rocks.

The Kitimat Terminal Area lies within the Kitimat Ranges, which are a subdivision of the Coast Mountains that extend south of the Nass River to the Bella Cola River. The Kitimat Ranges are flanked to the west by the Coastal Trough and to the east by the Hazelton Mountains. The topography is the result of valley and cirque glaciations, which produced drowned valleys, cirques that open to marine waters, and long fjords. The peaks of the Kitimat Ranges were covered by glaciers during the Pleistocene and exhibit a more rounded morphology than the peaks to the north. The area of outcrop examined lies within an unnamed intrusion of probable Middle Jurassic age. It is flanked to the west by the Tertiary Quotton Pluton (age dates range from 59-80 Ma) which is described as medium to coarse-grained hornblende-biotite quartz diorite to tonalite, with differentiated phases of quartz diorite, granodiorite and migmatitic quartz diorite orthogneiss. An unnamed intrusive suite of similar age and composition occurs on the east side of Kitimat Arm. To the north lies the Poison Pluton of probable Jurassic to Cretaceous age. It is described as biotite-hornblende quartz diorite or gabbro, which is unfoliated to weakly foliated.

Site Geology: The site consists of a large fresh roadcut exposure of unweathered rock. The outcrop is approximately 100 m in length, and 15 m in height. The lithologies consist of massive equigranular to locally foliated hornblende diorite cut by several episodes of increasingly felsic dykes. The early mafic phases are dark grey to black and

strongly magnetic, with accessory red garnet. Younger dykes range in colour from medium to pale grey, to pinkish white with decreasing mafic content, and appear to range in composition from monzodiorite to granite. Dykes range in width from centimeters to meters, are randomly oriented and can contain xenoliths of more mafic phases, which may be foliated. There is free quartz in the youngest dykes, which are locally transitional into pegmatites or hydrothermal veins. The ratio of mafic to felsic rocks is approximately 60:40. There are localized clots of coarse-grained (1-4 cm) euhedral pyrite crystals associated with early quartz veining in the mafic phases. These clots form rusty stains on the outcrop, 1-2 m^2 in size. These pyritic veins are cross cut by younger felsic dykes, which contain only trace amounts of pyrite. Overall pyrite content of the outcrop is <1%. There is minor pervasive epidote-calcite alteration of the intrusive rocks. Two samples representative of the mafic and felsic phases were collected to characterize the bulk of the rock, and a third sample that contains quartz-pyrite veining was collected to characterize the localized potentially ARD producing rock.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Term-001	9	518735	5977796	mafic phase
06-Term-002	9	518735	5977796	felsic dyke phase
06-Term-003	9	518735	5977796	rusty weathering pyrite-bearing vein

Site Name: West Side of Lower Kitimat Valley
NTS: 103I 02
UTM: Zone 9 519440E 5984094N
Photos 3 and 4
Physiographic Area: Kitimat Ranges
Reason for Concern: Rock exposed directly along proposed pipeline route

Regional Geology: Poison Pluton in contact with Hazelton Group Telkwa Formation
The Poison Pluton is a Jurassic to Cretaceous age biotite-hornblende quartz diorite to gabbro intrusion, belonging to the Coast Plutonic Complex. Along its eastern margin the pluton is in contact with the Telkwa Formation, which forms the lowermost unit in the Lower to Middle Jurassic Hazelton Group volcanic rocks. The Telkwa Formation consists of green to purple submarine to subaerial andesitic to rhyolitic flows, fragmental and pyroclastic rocks, basaltic flows and breccias, well bedded lapilli, crystal and ash-fall tuffs, welded tuffs, and volcaniclastic sedimentary rocks. The Telkwa Formation is host to known volcanogenic massive sulphide, copper porphyry and copper-iron skarn type showings.

Site Geology: Three separate outcrop sites were visited along a 3 km stretch of the pipeline, in the vicinity of the Alcan Plant site. At the first site (06-Alcan-001), the

Poison Pluton is exposed adjacent to the main road, in a large steep slope. The rock is a pale grey-green equigranular granodiorite with bleached sericite-chlorite altered mafic minerals. The rock is abundantly fractured, with calcite coating on fractures, and chlorite slickensides on slip surfaces. A few sparse quartz+/-chlorite veins are present. No sulphides were observed in the quartz veins, but sparse, very fine-grained rusty weathering pyrite veinlets are present in the intrusion. Overall sulphide content of the rock is <1%.

The second site (06-Alcan-002) consists of an outcropping fault contact between the Poison Pluton and Telkwa Formation volcanic rocks. The several meter high vertical to overhanging outcrop is located along the main road, and is partially obscured by vegetation. The. The contact is faulted, with interleaved slivers of intrusive and volcanic rock. Both rocks are pervasively chlorite altered, which partially obscures the protoliths. Epidote alteration occurs in veinlets, and reddish hematite occurs on fracture surfaces. A minor amount of pyrite is present as stringers and is finely disseminated in the wallrock. Overall sulphide content is <1%.

The third site is on a ridge outcrop, directly beneath a powerline midway between, and at a higher elevation than the other two sites. The site is accessed by a recent logging road. Outcrop exposures consist of a pale grey to white weathering, medium grained, equigranular granodiorite intrusion (Poison Pluton) with up to 15% free quartz. The rock is weakly to moderately magnetic due to the presence of minute cubic magnetite crystals. Primary mafic minerals are altered to blue-green chlorite. A rusty orange stain that was observed beneath the powerline during the recon trip is due to exposed B-horizon soils, in a recently disturbed road bed. No sulphides were observed, and as such, no ARD sample was collected here.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Alcan-001	9	519400	5984981	altered granodiorite
06-Alcan-002	9	518798	5986740	volcanic rock with pyrite, near contact with diorite
06-Powerline	9	518684	5986006	no sample collected

Site Name: Billy (MINFILE# 103I 218)
NTS: 103I 02
UTM: Zone 9 518404E 5998362N
Physiographic Area: Kitimat Ranges
Reason for Concern: MINFILE occurrence within 3 km of proposed pipeline route

Regional Geology: Hazelton Group Telkwa Formation
The Billy property is underlain by two greenschist facies metamorphic rocks: a Lower Jurassic, lapilli-lithic tuff, and coarse-grained volcanic breccia belonging to the Telkwa Formation. Both rock types are cut by basaltic, andesitic and quartz-feldspar porphyritic

dykes. Unnamed granite to granodiorite plutons of the Jurassic to Tertiary Coast Plutonic Complex lie to the west. Exploration targets consisted of quartz-sericite altered zones that lie within a structurally controlled fracture zone that strikes northeast and dips northwest. The showing consists of two small zones separated by approximately a kilometer. Gold and silver were the primary elements of interest.

Site Geology: The Billy showing lies on the northwest side of Bowbytes Creek, approximately 2.5 km west of the proposed alignment. The concern is that the pyritic alteration related to this site may be widespread. Access to the area is along logging roads that follow flat, thickly forested river valleys with no visible outcrop. There is a gain of over 500 m as the showing is approached, and it is ultimately exposed in a steep outcrop of rock adjacent to a logging road that is covered in second growth vegetation. The outcrop consists of volcanic rocks with sparse, partially digested fragments and plagioclase phenocrysts. Chlorite-epidote alteration is both pervasive and veinlet controlled. White quartz veinlets with minor amounts of pyrite are also present. Locally there are zones of intense pervasive silicification, accompanied by abundant, very fine-grained disseminated cubic pyrite. These zones are rusty weathering, but appear to be limited to a few square meters in extent. The general lack of outcrop in the area hinders a broader delineation of the potentially pyritic alteration zones.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Billy-001	9	518422	5998136	1-5% disseminated pyrite in quartz-chlorite-epidote altered volcanic rock

Site Name: J (MINFILE# 103I 221)
NTS: 103I 02
UTM: Zone 9 521871E 6002086N
Photo 5
Physiographic Area: Kitimat Ranges
Reason for Concern: MINFILE occurrence within 3 km of proposed pipeline route

Regional Geology: Coast Plutonic Complex, Hazelton Group Telkwa Formation
The area of the J MINFILE showing is underlain by andesitic tuffs of the Telkwa Formationthat are cut by granodiorite dykes related to the Poison Pluton of Coast Plutonic Complex. The showing is a potential volcanogenic massive sulphide-style deposit with stratiform pyrite-chalcopyrite in bedded tuffs that are exposed over a width of 0.5 m. Bands of pyrite up to several cm in width are reported in the tuffs exposed along the Wedeene River, and in a railway cut to the south.

Site Geology: The site was accessed by helicopter, which landed in the Wedeene River, near a railway bridge over the river. Rock is exposed on the south side of the river under and to the west of the bridge. Additional outcrop is also exposed in a railway cut less

than 50 m south along the railway line. Sulphide mineralization occurs at the subhorizontal contact of the underlying Telkwa Formation volcanic rocks and an overlying medium grained granodiorite body. The contact is subhorizontal. The granodiorite is also partially exposed in the forest behind these sites where there is some higher topographic relief. The volcanic rock is fine-grained, dark grey-green, and pervasively chlorite altered. There are irregular quartz-epidote-chlorite-calcite veinlets at the contact in both the volcanic rock and the intrusion. Minor amounts of pyrite and trace chalcopyrite were observed disseminated in both rock types. There is rusty weathering on fractures. A sample of each rock type was collected west of the bridge.

A sample was also taken from the outcrop adjacent to the tracks, which consists of fine-grained felted-texture volcanic rock with <3 mm calcite-infilled vesicles. There was approximately 1% very finely disseminated pyrite in the outcrop.

Granodiorite was exposed in the forest above the sample site.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-J-001	9	522008	6002151	<1% disseminated pyrite-chalcopyrite in chlorite altered volcanic rock
06-J-002	9	522008	6002151	<1% disseminated pyrite in chlorite-epidote-calcite altered granodiorite
06-J-003	9	522081	6002176	1% pyrite in fine-grained, felted, calcite-filled amygdaloidal volcanic rock

Site Name: Southeast Side of Hoult Creek
NTS: 103I 01
UTM: Zone 9 556803E 6005780N
Physiographic Area: Kitimat Ranges
Reason for Concern: Permissive geology within 3 km of proposed pipeline

Regional Geology: Coast Plutonic Complex, Hazelton Group Telkwa Formation
The area is underlain by unnamed Late Cretaceous to Paleocene granite and granodiorite intrusions of the Coast Plutonic Complex that intrude the Lower Jurassic Telkwa Formation andesitic tuffs, flows and breccias. Plutonic and volcanic rocks are cut by Tertiary-aged diabase dykes and northwest striking faults.

Site Geology: The site is a borrow pit that has been used during logging road construction. It occurs south of Hoult Creek, approximately 400 m south of KP 1081 on the proposed pipeline route. The lithologies consist of a fine-grained volcanic unit and fine-grained dioritic dykes up to several meters wide. The orientation of the dykes was not determined. Volcanic rock is generally aphanitic and partially biotite hornfelsed with

epidote-sulphide-magnetite+/-actinolite veinlets and overall sulphide content of <1%. There is also some evidence of layering, and possibly a cherty component in the volcanic package. A subvertical, northwest striking fault with minor gouge, and a narrow (<0.5m) halo of bleached silica alteration cuts the volcanic rocks.

Cross cutting dykes are massive, magnetic equigranular to weakly porphyritic, containing 40% 1-3 mm plagioclase, sparse pyroxene phenocrysts, and minor free quartz. Dyke margins are chilled and there is 1-2% finely disseminated, partially oxidized pyrite and possibly pyrrhotite in the dykes. . One sample from each rock type was collected.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Hoe-001	9	556803	6005780	aphanitic volcanic, epidote-sulphide-magnetite veinlets
06-Hoe-002	9	556803	6005780	plagioclase-pyroxene porphyritic dyke, 1-2% disseminated pyrite-pyrrhotite

Site Name: Hoult (MINFILE# 103I 164)
NTS: 103I 01
UTM: Zone 9 561129E 6006921N
Photos 6, 7 and 8
Physiographic Area: Kitimat Ranges
Reason for Concern: MINFILE occurrence within 3 km of proposed pipeline route

Regional Geology: Coast Plutonic Complex, Hazelton Group Telkwa Formation
The area is underlain by unnamed Late Cretaceous to Paleocene granite and granodiorite intrusions of Coast Plutonic Complex that intrude the Jurassic east-striking, north-dipping Telkwa Formation andesitic to rhyolitic tuffs, flows and breccias. Tertiary-aged diabase dykes and northwest striking faults cut both rock types. The Hoult MINFILE is a low-grade molybdenum-copper porphyry-style deposit that occurs as disseminated sulphides and mineralized quartz veins in both volcanic and intrusive rocks. The main reported mineralized area measures 1000 x 600 x 350 metres. Propylitic alteration consisting of epidote-chlorite-actinolite-pyrite-pyrrhotite is widespread.

Site Geology: The Hoult showing is exposed in a clear cut block adjacent to the pipeline route. The route lies parallels an existing logging road at the base of the cut block in this stretch. The logging roads on the slope above the route have provided fresh exposures of the intrusion and its contact with the Telkwa Formation volcanic rocks. The intrusion forms a prominent knob of outcrop on the slope, approximately 1 km wide along the logging road and extending approximately 250 to 300 m upslope. The intrusion is a massive pale pink, white weathering, medium grained, equigranular, granitic rock. The rock consists of interlocking plagioclase, K-feldspar, quartz and muscovite. Quartz content is variable, but ranges up to 40%. Disseminated to clotty or dendritic pyrite is

present and locally comprises up 4% of the rock. Quartz veins with clotty pyrite, molybdenite and chalcopyrite occur in the granite near its margins.

Above and to the northeast of the massive intrusion, the Telkwa Formation volcanic rocks are exposed. They are generally homogenous, very fine-grained and dark grey-green with a local weak foliation. Near intrusive contacts they are biotite-magnetite hornfelsed with a retrograde chlorite-epidote overprint. Pyrite and chalcopyrite occur in quartz veinlets and as blebs in the altered volcanic rock. Veinlet densities are up to 3 to 5 per meter and overall sulphide content averages <2%, with up to 5% sulphides in the veins.

Both the granitic intrusion and volcanic rocks are cut by a series of fine-grained, weakly porphyritic, dark grey magnetic dykes that have sharply defined chilled margins. They are northwest striking and moderately to steeply northeast dipping. These may be Tertiary-age diabase dykes. Alteration and sulphide mineralization are more strongly developed within both the granitic intrusion and the volcanic rocks near their mutual contacts, and at the contacts with magnetic dykes. Molybdenite coatings on fractures within the granitic intrusion appear to be spatially related to the younger magnetic dykes. An ARD sample of the weakly mineralized volcanic rock was collected. Two samples of the granite were collected, one near the top of the exposure, and one along the pipeline route.

At the edge of an adjacent clear cut block, just east of an unnamed creek and a decommissioned river crossing, an intensely altered outcrop of the granite occurs. Pervasive sericite/clay–pyrite alteration is developed around a small fault zone which strikes 120^o and dips 85^o SW. The rock is decomposed to clay and residual quartz, with abundant iron staining, semi-massive fine-grained pyrite. The altered exposure is less than several m^2 in area, and cannot be traced further due to lack of outcrop. A sample of this material was collected for ARD.

The Hoult MINFILE site poses several potential problems for the pipeline route. Sulphide mineralization occurs in both volcanic and intrusive rocks, and appears to be most intense around their contacts. The NW-SE striking faults in the area may also have sulphide mineralization associated with them.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Hoult-001	9	561092	6006993	chlorite-epidote altered volcanic
06-Hoult-002	9	561161	6006636	granitic intrusion, minor pyrite
06-Hoult-003	9	561061	6006629	granitic intrusion, minor pyrite
06-Hoult-004	9	561711	6006621	intense clay-pyrite altered fault gouge in granitic intrusion

Site Name: Nimbus Mountain / Nimbus Ridge
NTS: 103I 01-93L 04
UTM: Zone 9 567555E 6005887N
Photo 11
Physiographic Area: Kitimat Ranges
Reason for Concern: Tunnel route through mountain, copper oxide stain in cliff face

Regional Geology: Nanika Plutonic Suite, Hazelton Group Telkwa Formation
Nimbus Mountain occurs on the easternmost edge of the Kitimat Ranges. The proposed pipeline route tunnels through this mountain, emerging on the western side at Hoult Creek. The mountain is capped by a package of Telkwa Formation volcanic rocks, up to 700 m in thickness that are underlain by an unnamed, pale grey-pink sill-like intrusion of probable Eocene age (56.5-35.4 Ma), possibly part of Nanika Plutonic suite that vary in composition from equigranular granite to granodiorite to aphanitic rhyolite breccias. They occur as small plutons, dyke swarms and sills, along steeply dipping faults and are known to host porphyry and stockwork Cu-Mo mineralization. Outcrop exposure is extensive on the mountain and adjacent ridge, and has been the subject of detailed mapping as part of this pipeline project The contact between the volcanic rocks and underlying intrusion is well exposed, and sharply defined. The intrusion is up to 600 m in thickness, and appears to dip shallowly to the northwest. Dykes of similar composition cut the volcanic package. Late Cretaceous granitic intrusions, similar to those at the Hoult showing are exposed to the south, beneath the younger intrusions. Several northwest trending faults are mapped, cutting through the mountain, including the Nimbus, South Fork and Gully Faults.

Site Geology: Blue-green malachite staining was observed from the air on a relatively inaccessible cliff face, on the southeast flank of the mountain in a valley developed on the Nimbus Fault at an elevation of approximately 1600 m. The rock on the ridge (Nimbus Ridge) above the stain consisted of green, locally rusty weathering, fragmental volcanic rocks, cut by sparse quartz veining. Approximately 1-2% disseminated pyrite was present in the rock.

The concern on Nimbus Mountain is the potential for sulphide mineralization along the intrusive/volcanic contact.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Nimbus-001	9	567555	6005887	fragmental volcanic with disseminated pyrite and minor quartz veining

Site Name: Ridge above Clore River Canyon
NTS: 93L 04
UTM: Zone 9 573300E 6003400N

Photos 12 and 13
Physiographic Area: Kitimat Ranges
Reason for Concern: Outcrop directly on proposed pipeline route

Regional Geology: Intrusions of uncertain affinity, Hazelton Group Telkwa Formation
The proposed pipeline route lies along a west-northwest to northwest trending ridge on the eastern edge of the Kitimat Ranges on the southwest side of the Clore River, which has cut a steep, 400 m inaccessible canyon along this stretch of the pipeline. The area is underlain by layered Telkwa Formation volcanic rocks, and unnamed intrusions. Recent detailed mapping by Peter Reed covers this area down to the confluence of the Clore and Burnie Rivers. The new mapping is far more detailed than existing mapping and discrepancies in rock patterns between old and new mapping are apparent. There is also uncertainty as to whether these intrusions are part of the Eocene aged Nanika Plutonic Suite or the older Coast Plutonic suite. The North Hope Fault, one of the northwest trending set of faults in the region, cuts across this ridge.

Site Geology: The ridge is an area of complex geology. There is abundant outcrop due to sparse alpine vegetation, the recent retreat of ice and fracturing and downslope movement of the rock. The lowermost exposed unit is a homogenous very fine-grained dark black-green volcanic rock. It is strongly magnetic with clots of pyrite-pyrrhotite, as well as disseminated magnetite. Sulphide content is approximately 1%. This unit is overlain by a paler green-grey fragmental volcanic flow and crystal tuff with plagioclase phenocrysts, which grade up into a flow banded rhyolite. The rhyolite is medium grey, weathering to white. Rusty weathering chlorite-magnetite veinlets and clots are present in the rhyolite. Veinlets of pyrite-pyrrhotite-chalcopyrite+magnetite occur at the fragmental volcanic/rhyolite contact. Sulphide content is up to 2%, and the host rocks look partially silicified. There are no MINFILE occurrences noted in this area. Along the top of the ridge a felsic porphyritic to equigranular intrusion, and potentially related dykes outcrop. Plagioclase phenocrysts up to 3 mm in length are abundant and free quartz is present in the porphyritic phase. There are also zones of pervasive, sugary textured white quartz. It is unclear if this is vein material or pervasive alteration. There does not appear to be any sulphide mineralization associated with this quartz. Two samples were collected on this ridge, one of the dark underlying volcanic rock, and one of the mineralization at the rhyolite contact.

A second site was visited along this ridge, on the southwest side of the North Hope Fault which appears as a talus-covered notch in the ridge. A large exposure of extensively weathered granite is exposed on the southwest side of the fault; feldspars are pervasively sericite altered, and the intrusion has weathered to a coarse-grained sand. Pieces of medium grey porphyritic dyke material are visible in float. From the air, on the steep western flank of the ridge, a set of sheeted, subvertical grey dykes were seen cutting the pale granitic intrusion. No samples were collected from this portion of the ridge.
The proposed alternative route for the pipeline runs through the valley floor on the southwestern side of this ridge. This area is covered in marshland and forest and no outcrop was visible directly on this proposed route.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-CloreR-001	9	573428	6003320	fine grained dark grey andesitic volcanic with pyrite
06-CloreR-002	9	572958	6003477	flow banded rhyolite overlying andesite, mineralization at contact

Site Name: Nanika Intrusion, Confluence of Burnie and Clore Rivers
NTS: 93L 04
UTM: Zone 9 577545E 6002150N
Photo 14
Physiographic Area: Bulkley Ranges
Reason for Concern: Outcrop adjacent to proposed pipeline route

Regional Geology: Nanika Plutonic Suite, Hazelton Group Telkwa Formation
The Nanika Plutonic Suite intrusion includes granite, minor rhyolite and grey to pink porphyritic to equigranular stocks, dykes and sills, which range in composition from granodiorite, quartz monzonite. They are Eocene in age (54-47 Ma), occur in the rugged Bulkley Ranges of the Hazelton Mountains. They intrude Telkwa Formation volcanic rocks, and are known to host Cu-Mo porphyry deposits. The Bulkley Ranges are characterized by serrate peaks greater than 2000 metres above sea level, wide valleys, and upland plateaus of alpine tundra.

Site Geology: The proposed pipeline route skirts around a topographic high 1.5 km east of the confluence of Burnie and Clore rivers. This knob is shown as a small stock (approximately 3 km^2) belonging to the Nanika Plutonic Suite. The intrusion does not appear to outcrop in the hill, which is covered in fine-grained dark grey volcanic rock, with possible calcite-filled amygdules. Two samples of the volcanic rock were collected.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-INT-001	9	577487	6002003	fine-grained dark volcanic, weak chlorite alteration, calcite veinlets
06-INT-002	9	577545	6002150	fine-grained dark volcanic, weak chlorite alteration, calcite veinlets

Site Name: Rose Formation
NTS: 93L 04
UTM: Zone 9 576001E - 578299E, 6000358N – 6003724N

Physiographic Area: Bulkley Ranges
Reason for Concern: Permissive Geology along proposed alternate pipeline routes

Regional Geology: Skeena Group Red Rose Formation
The Skeena Group is composed of a Lower Cretaceous sedimentary-volcanic package that rests unconformably on the Jurassic Hazelton Group and consists of up to 2000 m of conglomerate, sandstone, shale and minor coal beds overlain by several hundred meters of subaerial basaltic to andesitic porphyritic volcanic flows, tuffs and breccias. The volcanic rocks are in turn overlain by a sequence of marine shale and chert pebble conglomerate of variable thickness. The uppermost unit, the Red Rose Formation, is up to 300 m thick and consists of siltstone/mudstone, chert pebble conglomerates and coal. Black mudstone layers in the Red Rose are known to be pyritic.

Site Geology: Several sites were visited along the length of the Burnie River, within a kilometer or less of the proposed alternate north and south routes for the pipeline. At the southernmost site, black, rusty weathering shales were exposed on the east bank of the Burnie River. The rock is highly fissile, and fracture surfaces are iron stained. Very fine-grained cubic pyrite is present on fractures, but there is also evidence of very fine-grained Fe-carbonate porphyroblasts in the matrix of the rock, which may also contribute to the iron staining. Unweathered pyrite is rare. Where iron staining is not present, the rock weathers to pale grey. Several subvertical, hornblende-plagioclase porphyritic dykes that may belong to the Nanika Plutonic Suite and are associated with sericite alteration crosscut the shale and contain up to 5% disseminated pyrite. The west side of the river was not accessible, but appeared to be a different rock type; a coarser-grained, grey layered rock, with apparent bedding striking 270^{o}, dipping 80^{o} northwest. Two samples were collected at this site, one of the black shale (06-Rose-001) and one of the dyke (06-Rose-002).

The second site was on the west side of the Burnie River, 0.5 km north of the proposed southern route. Outcrop along the river consisted of a dirty, unsorted sandstone/ arkose with abundant white mica, fine-grained sandstone, and siltstone with possible trace fossils. On the opposite inaccessible bank there appeared to be black shale, which suggests there is a northerly trending contact, possibly a fault, which the Burnie River partially follows. Two samples of the clastic rocks were collected (06-Rose-003, -004).

The third site was along a prominent ridge 0.5 km east of the Burnie River, 200 m from the proposed northern alternate route. This knob is shown on government maps as Skeena Group. It is comprised of fine-grained green volcanic rocks that may be part of the Skeena Group, with weak pervasive chlorite alteration and manganese staining on fracture surfaces. Plagioclase and pyroxene phenocrysts are locally visible and white calcite veins are moderately abundant. The rocks weather a reddish buff colour. The volcanic rocks were cut by a limited number of fine-grained grey, weakly plagioclase-phyric dykes, similar to those observed at the first site that may be part of Nanika Plutonic Suite. A sample of the volcanic rocks was collected (06-Rose-005).

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Rose-001	9	576001	6000358	carbonaceous siltstone/shale
06-Rose-002	9	576009	6000433	hornblende-plagioclase porphyritic dyke, cutting shale, sericite alteration
06-Rose-003	9	576323	6002087	very fine grained, mica rich sandstone
06-Rose-004	9	576147	6001370	fine grained siltstone, possible trace fossils
06-Rose-005	9	578299	6003724	fine grained dark volcanic, weak chlorite alteration, calcite veinlets

Site Name: Copper Star (MINFILE# 093L 326)
NTS: 93l 03
UTM: Zone 9 612916E 6010404N
Physiographic Area: Nechako Plateau
Reason for Concern: MINFILE occurrence within 3 km of proposed pipeline route

Regional Geology: Skeena Group, Hazelton Group, Bulkley Suite
The Copper Star showing is a low-grade porphyry style deposit, located within the Nechako Plateau which is the northernmost subdivision of British Columbia's Interior Plateau. It spans the basin of the Nechako River and its tributaries, and is bounded by the Hazelton Mountains to the west, and the McGregor Plateau to the east. The Nechako Plateau is an area of low relief with large surfaces of flat or gently rolling topography. Most of the plateau is covered by thick glacial sediments, and there is very little bedrock exposure. The Copper Star MINFILE occurs near a faulted contact between the Cretaceous Skeena Group sedimentary-volcanic rocks, and the Jurassic Telkwa Formation volcanic rocks. A small intrusion of quartz monzonite, possibly belonging to the Late Cretaceous Bulkley intrusive suite, was uncovered along a logging road. Intrusions of the Bulkley Suite are biotite-hornblende bearing diorite to granite, with most rocks having an intermediate composition. They occur as dykes swarms, small stocks and batholiths. Many intrusions have well developed contact metamorphic aureoles. Many of the smaller intrusions are known to host Cu-Mo porphyry deposits. Drilling around the showing has delineated a stock at least 1 km in length. The surrounding volcanic rocks are either biotite hornfelsed, or locally sericite-clay altered, with up to 5% pyrite adjacent to the intrusion. Pyrite-chalcopyrite-molybdenite are present as disseminations and fracture-fill in unaltered to weakly altered porphyritic intrusions. Drilling and prospecting has uncovered other occurrences of Cu-Mo mineralization in the area in float and bedrock, but the overburden cover has hindered delineation of the mineralization.

Site Geology: An outcrop of a mostly unweathered, moderately magnetic porphyritic stock along a logging road was located 1.5 km north of the proposed pipeline route. The rock consists of plagioclase-hornblende-biotite quartz monzonite with minor K-feldspar-chlorite alteration around microfractures. Minor amounts of chalcopyrite with malachite

staining occur in blebs. Approximately 200 m east along the logging road, olive green volcanic rocks with pervasive clay-chlorite alteration are exposed. There are sparse quartz veins, which have trace amounts of pyrite in and adjacent to them, as well as silicification of the volcanic rock, and minor calcite alteration. A stack of drill core was located in a clearing just north of KP 1017, which rock consists of dark green to black, locally biotite hornfelsed volcanic rock, with both pyrite-coated fractures, and pink and white calcite-coated fractures. The porphyritic intrusions in the boxes were weakly propylitically altered.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
Copper Star	9	612831	6010387	intrusion, no sample taken
Drill Core	9	614850	6009700	core, no sample taken

Site Name: Volcanic Rocks
NTS: 93L 03 – 93L 02
UTM: Zone 9 various sites
Photos 15 and 16
Physiographic Area: Nechako Plateau
Reason for Concern: Permissive geology along proposed pipeline route

Regional Geology: Hazelton Group Telkwa Formation, Kasalka Group
The Nechako Plateau is underlain by Lower Jurassic Hazelton Group Telkwa Formation volcanic rocks, Lower Cretaceous Skeena Group sedimentary-volcanic rocks and Cretaceous Kasalka Group andesitic volcanic rocks. Outcrop is very limited in this area and contacts between units are not visible. These formations are known host to mineral showings, and any available outcrop along the proposed pipeline route was examined. The Telkwa Formation is described as maroon, green and purple subaerial andesitic to dacitic pyroclastic and fragmental rocks, flows with flow top breccias, well bedded lapilli, crystal and ash-fall tuffs, welded tuffs and volcaniclastic sedimentary rocks. The volcanic package within the Skeena Group is described as subaerial to submarine basalt to andesite flows, locally pillowed and amygdaloidal, with green to maroon tuffs, breccias and intercalated volcaniclastic sedimentary rocks. The Kasalka Group is described as predominantly andesite flows with related polymicitic breccias, lapilli and crystal tuffs, local porphyritic dacite, and flow banded rhyolite. The flows are in part extrusive equivalents of the Bulkley Intrusions.

Site Geology: Volcanic rocks were examined at three separate sites. The westernmost site lies very near the projected western contact of a strip of Skeena Group and Telkwa Formation. It is not clear from the regional map if the volcanic unit of the Skeena Group would be expected at this location; it may be Telkwa Formation. The rusty-weathered roadside outcrop consistes of massive maroon coloured, hematitic matrix supported polylithic fragmental volcanic rock. A sample of the outcrop was collected (06-Telk-002).

The second site is likely Telkwa Formation, but occurs at the projected eastern of contact of Skeena Group with the Telkwa. This site is a large (120 m x 25 m), cliff exposure of well bedded volcanic rocks and minor intercalated sediments. It grades from a basal unit of augite-phyric flows, through fine-grained plagioclase-phyric to aphanitic flows up into hematitic lapilli tuffs, with silt-sand interbeds. Bedding/flow banding strikes 40^o and dips 22^o southeast. The tuffs are intensely fractured, with abundant calcite coated fractures and less common cross cutting calcite veins. There is a large apron of colluvium at the base of the cliffs, which has been cemented in place with calcite. Material from this exposure has been used for roadbed material. A sample (06-Telk-001) was collected near the base of the cliff, and did not include the calcite cemented material.

The third, easternmost site occurs near the contact with Telkwa Formation and Kasalka Group The sample site is a ridge of outcrop in an otherwise overburden covered area. The rock is a fragmental volcanic rock with abundant mm to cm sized polylithic fragments supported in a maroon coloured matrix. Fragments are in the mm to cm range, and are polylithic. It was not observed in outcrop, but angular pieces of green, vesicular, magnetic volcanic rock occurs in float on the fragmental outcrops. A sample of the fragmental rock was collected (06-Mor-001).

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Telkwa-001	9	624866	6007877	bedded andesitic? flows and tuffs, with caliche cementation of colluvium at base
06-Telkwa-002	9	613767	6008886	purple matrix supported fragmental volcanic rock
06-Mor-001	9	633507	6010506	purple matrix supported fragmental volcanic rock

Site Name: Chisholm Lake / Gold Stream (MINFILE# 093L 159 / 093L 160)
NTS: 93L 03
UTM: Zone 9 616426E 6009873N / 617493E 6007118N
Physiographic Area: Nechako Plateau
Reason for Concern: MINFILE occurrences within 3 km of proposed pipeline route

Regional Geology: Skeena Group
This part of the Nechako Plateau is underlain by Lower Cretaceous Skeena Group marine sedimentary rocks including sandstone, siltstone, shale, and chert pebble conglomerate, as well as andesitic to basaltic volcanic flows, tuffs and breccias. In the vicinity of the showings the Skeena Group consists of coarse clastic rocks that dip 20-50^o to the east and typically contain an abundance of fine-grained, detrital muscovite. The Chisholm Lake showing is described as a single 1.5 m thick bed of coal exposed in a creek bed;

subsequent drilling failed to delineate the extent of this unit. The Goldstream showing is comprised of multiple coal seams up to 1.7 m thick over an area approximately 4.0 km x 3.2 km.

Site Geology: The showings occur in an area of subdued topography and very little outcrop exposure. The areas have been logged, which has provided access to some exposure. In the vicinity of the Chisholm Lake showing, a poorly sorted, olive-tan coloured, micaceous, medium-grained arkose is locally exposed in the road and in open areas of uncut forest. The creek is thickly vegetated, the original coal seam was not located and no sample was collected.

In the Goldstream showing area, there is a large clear cut block where large (>20m^3) blocks of the same dirty arkosic rock seen at Chisholm Lake were observed. Very rare thin laminations were also noted, and possible trace fossils, either worm burrows or replaced roots are present. A few black fragments of possible plant material were also observed, but no coal seams were located. The large blocks do no appear to be in place, as fracture patterns and possible bedding in the blocks are randomly oriented. No sample was collected.

A third site in the arkose was examined along the logging road just south of Chisholm Lake itself. This arkose was grey-green, fine-grained, with flakes of white mica.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
Chisholm Lake	9	616761	6010236	no sample collected
Goldstream	9	617557	6007029	no sample collected
outcrop	9	615934	6007748	no sample collected

Site Name: Silver Streak (MINFILE# 093L 327)
NTS: 93L02
UTM: Zone 9 646258E 6007483N
Photo 17
Physiographic Area: Nechako Plateau
Reason for Concern: MINFILE occurrence within 3 km of proposed pipeline route

Regional Geology: Kasalka Group
The showing occurs near the contact with the Kasalka Group and Telkwa Formation volcanic rocks. The mid-Cretaceous (100-83 Ma) Kasalka Group unconformably overlies the Skeena Group sedimentary rocks. It is comprised of up to 650 m of hornblende-feldspar porphyritic andesite flows and related fragmental rocks, with lesser amounts of dacite to rhyolite flows, and tuffs. These are overlain by a package of lahars up to 1000 m thick, and an upper package of latite-andesite flows up 300 m thick. Porphyritic flows may be the extrusive equivalents of the Bulkley Intrusive suite, which

intrude the volcanic rocks. The Silver Streak showing is described as disseminated pyrite, with possible tetrahedrite, galena and sphalerite in a 9 m thick lapilli tuff horizon, overlain by shale. The tuff was cut by northwest trending carbonate veins.

Site Geology: The site of the showing indicated by the UTM coordinates has been blasted and used for road fill. The only rock visible in the pit was a fine-grained, dark grey-green crystalline andesitic volcanic rock cute by opalline quartz and bladed calcite veins. It is rusty weathering, but no sulphides were observed. The rock is not magnetic. A prominent northwest trending ridge of rock just west of the site, approximately 500 m in height, is composed of basalt-andesite flows of the Telkwa Formation. The tuff and argillite units described in the Silver Streak MINFILE were not observed. The Telkwa volcanic flows are well exposed in numerous ridges, but outcrop of the Kasalka Group is sparse in the area.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Streak-001	9	646321	6007516	fine grained andesite with calcite veins

Site Name: Bulkley Intrusion
NTS: 93L 02
UTM: Zone 9 654723E 6011610N
Physiographic Area: Nechako Plateau
Reason for Concern: Outcrop directly along proposed pipeline route

Regional Geology: Bulkley Intrusive Suite
The Bulkley Intrusive Suite is Late Cretaceous in age (84-64 Ma) and ranges in composition from biotite-hornblende diorite to granite, though most intrusions are granodiorite or quartz diorite. Intrusions occur as dykes swarms, sills, stocks, and minor intrusive breccias. Large plutonic bodies are generally unfoliated and appear to have been intruded at shallow crustal levels. Many of the smaller bodies are host to copper-molybdenum porphyry-style mineralization.

Site Geology: The proposed pipeline route crosses small stocks of the Bulkley Intrusive Suite. A small exposure of the stock was located along a road 500 m north of KP 976. At this location, the rock is a pale pink, white weathering equigranular felsic intrusion of possible granite or granodiorite composition. There are sparse (<5%) quartz eyes, weathered white mica and possibly biotite. No sulphides were observed nor was the contact with Kasalka Group volcanic rocks.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Bulk-001	9	654723	6011610	felsic intrusion, pale pink with sparse

				quartz eyes

Site Name: Equity Silver Mine (MINFILE# 093L 001), Klo River and Volcanics Rocks West of Equity Silver Mine, Volcanic Rocks East of Equity Silver Mine
NTS: 93L 01
UTM: Zone 9 678550E 6008059N
Photos 18 - 23
Physiographic Area: Nechako Plateau
Reason for Concern: Past Producing mine within 3 km of proposed pipeline routes

Regional Geology: Skeena Group, Endako Group, Goosly Lake Plutonic Suite
The Equity Silver mine is a past producing epithermal-style silver-gold mine. Mineralization was exposed in an erosional window of uplifted Cretaceous Skeena Group sedimentary and volcanic rocks, which are overlain by shallow dipping Endako Group basalt to andesite flows. A stock of the Goosly Plutonic Suite occurs to the east of the deposit. The Endako Group volcanics and the Goosly Intrusions are Eocene in age. The Skeena Group is divided into three stratigraphic units, a lower clastic unit, a middle pyroclastic unit that hosts the mineralization, and an upper mixed sedimentary-volcanic unit. The Endako Group is divided into the Goosly Lake Formation and the Buck Creek Formation. The Goosly Lake Formation is described as a trachyanedsite to basalt, and minor syenite, with tabular plagioclase phenocrysts. It is up to 500 m thick. The volcanic rocks are coeval with the Goosly Lake intrusions, which are gabbro to syenomonzonite in composition, with bladed feldspar phenocrysts (54-48 Ma). The Buck Creek Formation (48-43 Ma) consists of andesite to basalt flows, which are generally fine-grained, amygdaloidal and flat lying. They directly overly the Goosly Lake volcanic rocks. The best developed section of Buck Creek Formation is along Klo Creek, where the sequence is 300 m thick. The Goosly Lake intrusions are not related to mineralization.

Within the Equity Silver ore deposit, the main sulphide minerals are pyrite, chalcopyrite, pyrrhotite and tetrahedrite, accompanied by advanced sericite clay alteration. Mineralization occurred as veins and massive replacement bodies. The mine ceased production in January 1994. The tailings proved to be acid generating and environmental reclamation and mitigation work is ongoing.

Site Geology: Numerous sites were visited in and around Equity Silver. The proposed route of the pipeline is mainly through low lying areas in the Foxy Creek valley where there is very little outcrop and extensive overburden. Endako volcanic rocks that overlie the mineralized horizons within the Skeena are exposed mainly in ridges on the sides of the valleys, and within valley creeks. The first site examined is a prominent bluff of layered Endako Group Goosly Lake Formation volcanic rocks approximately 1 km north of the mine site. The layers consist of stacked flows of vesicular basaltic rocks with rubbley flow tops or bases. The mineralized pits on the mine site are partially flooded and were only observed from a distance.

The Goosly intrusions are exposed in a borrow pit immediately southeast of the Equity tailings dam. The pit is comprised of a series of dykes and flows of syenomonzonite(?) composition, ranging in texture from aphanitic or glassy, to coarse-grained porphyritic. The oldest unit in the pit is a fragmental volcanic that is possibly a flow. It is cut by brittle faults and numerous dykes with variable textures. The rocks are a reddish brown, with variable quantities of characteristic white tabular plagioclase phenocrysts. These crystals are platy; they are equant and up to 2 cm across in one dimension, but only millimetres thick. Locally these phenocrysts comprise up to 50% of the rock, and are trachytic. There is abundant crystalline Fe-carbonate in veins, on fracture coatings, and associated with the faulting. No sulphides were observed.

Fine-grained green volcanic rocks are exposed along a creek/ditch approximately 1 km below the tailings dam. One site of dark porphyritic rock, associated with localized intense quartz-pyrite alteration was observed on the stretch of existing logging road that parallels the proposed southern alternate route, around KP 949-950. Outcrop was also investigated in a steep canyon area on Foxy Creek approximately 500 m north of the proposed route. Layered basaltic flows of the Buck Creek Formation are exposed down to the creek bed. Interflow contacts tend to be rubbley and rusty weathering, but no sulphides were observed. Above the canyon, in the clear cut blocks, the volcanic rocks are generally covered in overburden. A few knobs of vesicular basalt flows, and laminated, buff coloured tuffaceous interbeds that were previously mapped as Buck Creek Formation are exposed in a cut block 6 km east of the mine site, 0.5-1.0 km north of the proposed route, around KP 944-943.

A second blasted borrow pit area was examined northwest of the mine site, adjacent to the road. The rocks are a series of flows, up to several metres thick, similar in texture and composition to the porphyritic syenomonzonite Goosly intrusions exposed in the mine site borrow pit. An 80 m long outcrop of Buck Creek Formation exposed along a roadcut 12 km east of Equity Silver Mine at Klo Creek was examined and sampled. The exposed volcanic rock is massive, fine-grained and magnetic, with minor amounts of pyrite associated with magnetite.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-EM-001	9	678776	6010126	fg grey volcanic, in drainage ditch north of NAG quarry
06-EM-002	9	679489	6010865	fg green volcanic disseminated pyrite minor $CaCO_3$ veins
06-EM-003	9	679996	601705	fg green volcanic in cut block on south alternate route
06-EM-004	9	680483	6010513	dark intrusive with feldspar phenocrysts
06-EM-005	9	680483	6010513	dark intrusive with feldspar phenocrysts
06-EM-006	9	680483	6010513	highly altered volcanic with euhedral pyrite and quartz
06-EM-007	9	679553	6010859	

06-Foxy-001	9	682442	6012911	basalt/andesite volcanic flows in Foxy creek, Endako Group
06-Endak-001	9	685117	6014933	volcanic, Endako basalts outcrop knob in clearcut
06-Endak-002	9	685382	6013908	tuffaceous layers within Endako basalts
06-EMW-001	9	671945	6011156	red andesite/basalt flow, $CaCO_3$ in vesicles, above grey flows
06-EMW-002	9	671945	6011156	grey andesite/basalt flow, weakly magnetic
06-KLO-001	9	666293	6012250	Endako Group Buck Creek volcanic

Site Name: Hanson Lake (MINFILE# 093K 078)
NTS: 93K 06
UTM: Zone 10 368776E 6013952N
Photo 24
Physiographic Area: Nechako Plateau
Reason for Concern: MINFILE occurrence within 3 km of proposed pipeline

Regional Geology: Taltapin Metamorphic Complex, Stern Creek Plutonic Suite, Nechacko Plateau Group
The Hanson Lake showing is a porphyry-style copper-gold-molybdenum occurrence in an area of complex geology, within the overburden covered Nechako Plateau. The area is underlain by a metamorphic complex of Carboniferious to Jurassic Cache Creek assemblages, and a gneissic complex of Late Triassic Stern Creek Plutonic Suite granodiorites. These rocks are intruded by Tertiary (Eocene to Oligocene) quartz-feldspar porphyries, and overlain by Tertiary Nechako Plateau Group andesitic volcanic and sedimentary rocks. Mineralization in this unit occurs as fracture fill in Tertiary quartz monzonite, shear zones in quartz diorite, and as pervasive silicification in porphyritic rocks.

Site Geology: The Hanson Lake Showing lies approximately 1 km to the south of the proposed pipeline route. There is very little outcrop along logging roads or in clear cut blocks. An area of subcrop/outcrop of biotite gneiss was examined on a stretch of road running sub-parallel the route, approximately 500 m to the south of KP 869. It was partially epidote altered and contained <1% disseminated pyrite. There was no access to the Hanson Lake showing itself, however the diamond drill from a 1990 drilling campaign was found stacked adjacent to the logging road. In the core, the main country rock is amphibolite grade gneiss, comprised of hornblende-biotite-plagioclase, with finer-grained more mafic-rich segregations. There is localized disseminated and veinlet controlled mineralization consisting of pyrite-chalcopyrite and possibly bornite associated with chlorite-epidote-calcite alteration. Sulphide content is locally up to 5%. The gneiss is cut by a quartz-plagioclase rhyolite porphyry, with a white siliceously altered groundmass and 1-2% very fine-grained disseminated cubic pyrite . A fine-grained, grey, sugary textured intrusive phase is characterized by finely disseminated

magnetite also present. A sample of the mineralized gneiss and the rhyolite dyke were collected.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Hanson-001	10	368343	6015219	drill core, 4.6-13m down hole depth, altered rhyolite dyke
06-Hanson-002	10	368343	6015219	drill core, 22.2-29.0m down hole depth, mineralized gneiss
06-Hanson-003	10	367475	6014708	subcrop gneiss, minor pyrite, KP 869

Site Name: Misinchinka Group - Missinka River
NTS: 93I 12
UTM: Zone 10 568322E - 576327E, 6050971N - 6053061N
Photos 25 - 28
Physiographic Area: Misinchinka Ranges, Northern Rocky Mountains
Reason for Concern: Permissive geology

Regional Geology: Misinchinka Group – metamorphosed equivalents of the Miette Group
The proposed pipeline route follows the north side of Missinka River, through the Misinchinka Ranges (subdivision of Hart Ranges) on the western edge of the Rocky Mountains. The area is underlain by the Misinchinka Group, which is the metamorphosed equivalent of the Proterozoic age Miette Group and Lower Cambrian McNaughton Formation. The Miette Group is comprised of pebble conglomerate, argillite, siltstone, dolomite and minor sandstone, and limestone. The Lower Cambrian rocks are composed of pebble conglomerate, siltstone, argillite and quartzite. Within the Misinchinka Group, these rocks are metamorphosed into phyllites and coarse grained quartz-rich schists. The rocks are locally pyritic, and therefore of concern for ARD potential.

Site Geology: Several sites were examined both north and south of the Missinka River, were bedrock was intermittently exposed in logging roads, over an approximate 7 km length. The rocks are an alternating sequence pale silver-grey phyllite, and coarse grained schist, derived from quartz pebble conglomerates. The phyllite is highly fissile, and exhibits three distinct foliations. The dominant foliation is S2, which strikes 130-140^{o}, and dips moderately to steeply to the southwest. It is overprinted by spaced S3 kink bands, which strike northeast, and dip steeply southeast. Pyrite porphyroblasts are disseminated throughout the phyllite, ranging from minor amounts up to 10%. They are flattened in the plane of the S2 foliation, and are generally <3 mm in size. Relict bedding is visible in the phyllite, and its angular relationship to S2 varies from near parallel to high angles, indicating that it is tightly folded about S2.

The coarse-grained schist of the Misinchinka Group forms resistant knobs of outcrop. Locally, the quartz pebble conglomerate texture is well preserved, and all stages of deformation from weak to intense can be seen. Foliation is defined by alignment of muscovite, and elongation of the pebbles. Blue translucent quartz pebbles are common, as are slivers of phyllite that appear to be rip-up clasts of mudstone, but may also have been tectonically incorporated. The coarse schist is cut by abundant white quartz veins up to several meters in thickness, but of limited strike length. Some of these veins are sigmoidal. No sulphides were observed in the veins, and there is generally only trace amounts of sulphides present in the schist. Several samples of both rock types were collected.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Miss-001	10	568738	6052401	silver grey phyllite, minor disseminated cubic pyrite
06-Miss-002	10	568322	6052500	silver grey phyllite, disseminated cubic pyrite
06-Miss-003	10	567097	6053045	orthoquartzite-schist, trace pyrite
06-Miss-004	10	567336	6053061	orthoquartzite-schist, trace pyrite
06-Miss-005	10	576327	6050971	silver grey phyllite, disseminated cubic pyrite
06-Miss-06	10	577320	6050893	silver grey phyllite

Site Name: Miette Group
NTS: 93I 12
UTM: Zone 10 582249E – 584287E, 6051099N – 6053515N
Photos 29 and 30
Physiographic Area: Misinchinka Ranges, Northern Rocky Mountains
Reason for Concern: Permissive geology

Regional Geology: Miette Group – Middle Miette Formation
The proposed pipeline route along the north side of Missinka River, crosses into the Middle Miette Formation at approximately KP 642 and crosses to the south side of the river valley approximately 1 km further east. The Miette Formation is comprised of pebble conglomerate, argillite, diamictite and minor limestone. Pyrite within the argillites is the primary concern within this package of rock. The valley is generally filled with alluvium and lacustrine clays, but bedrock is exposed in borrow pits, and logging road cuts.

Site Geology: Black pyritic argillite/shale was examined in outcrop in three sites along roads, two locations less than 500m north of the proposed route on logging road cuts, and one site 1 km south of the route in a small borrow pit. The sites are spread out over an approximate 3 km length. The rock is fissile, and highly rusty weathering due to the

presence of abundant coarse-grained quartz-pyrite veins, as well as disseminated euhedral pyrite. Overall pyrite content is up to 10% with much higher concentrations of euhedral in veins up to several centimeters thick. The dominant foliation is 130-140^{o}, dipping to the southwest (consistent with the S2 fabrics in the Misinchinka Group) at a high angle to bedding where observed. The quartz-pyrite veins cross cut the foliation, but are also deformed, indicating a syn-deformation timing. Spectacular fibrous quartz pressure shadows are locally developed on large (2 cm) cubic pyrite porphyroblasts. This black pyritic shale has been used to cover portions of the logging road, and to reinforce bridge abutments over two small creek crossings. A pool of standing water in the borrow pit for the road bed material had a pH of 3.5.

A small outcrop of grey-green phyllite, with quartzite clasts and minor amounts of pyrite was also observed between the black shale sites.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Miss-007	10	584287	6053515	black argillite, quartz-pyrite veins
06-Miette-001	10	582923	6051099	quarry, black argillite, disseminated and vein pyrite
06-Miette-002	10	582923	6051099	quarry, black argillite, disseminated and vein pyrite
06-Miette-003	10	582249	6051929	black argillite, disseminated and vein pyrite
06-Miette-004	10	582325	6052004	quartz-pyrite veins in black argillite

Site Name: Besa River Formation
NTS: 93I 14
UTM: Zone 10 611237E – 613276E, 6068924N – 6069177N
Photos 31 - 34
Physiographic Area: Hart Ranges, Northern Rocky Mountains
Reason for Concern: Permissive geology

Regional Geology: Besa River Formation, Palliser Formation
The proposed pipeline route crosses into the Hart Ranges of the Rocky Mountains around KP 605. The Hart Ranges are comprised of tightly folded Ordovician to Permian limestone, dolomite, shale, and minor sandstone and chert. The Besa River Formation is a Devonian to Carboniferous black shale that is known to be pyritic. To the west, the Besa is in contact with the Upper Devonian Palliser Formation

Site Geology: A good exposure of the Besa River Formation occurs along an approximately 1 km stretch of Imperial Creek that is 1 km south of the proposed pipeline route. The rock is dominantly black carbonaceous shale with minor dark grey-brown, silty limestone/dolomite interbeds. The shale is highly fissile, fractured and folded with

the dominant foliation varying from nearly flat lying to nearly vertical along the creek bed exposure, but with a consist south to southwest dip. The outcrop is rusty weathering with yellow and white sulphur precipitates that are easily dissolved in water. The rusty weathering is caused by the presence of pyrite/marcasite nodules which range from <1 cm up to 30 cm in diameter. They are highly reactive, and coated in white sulphur-oxides or salts. The nodules are not evenly distributed within the shale but appear to be confined to certain horizons 10’s of cm in thickness, however the rusty staining, caused by the nodules, is widespread on fracture/foliation surfaces. The pyrite/marcasite in the nodules is extremely fine-grained, and concentrically banded. A few bedding parallel, pyrite-rich lamina were also observed, but are rare. Dolomite increases in abundance both up and downstream of the main shale exposure. A single large 1.5 m wide fault that strikes 316^{o} and dips 86^{o} northeast is infilled with extremely coarse-grained crystalline white calcite

The Palliser Formation was examined in a road cut above the Imperial River, directly on the proposed pipeline route. The actual contact with the Besa Formation is not exposed, though fissile grey-black siltstone/shale that is northwest striking and southwest dipping is exposed. There were no pyrite nodules observed, however there were completely weathered out pits, which may have been pyrite porphyroblasts.

West of the shale, a ridge of fossiliferous limestone that contains undeformed rugose and branching corals, bivalves, pieces of crinoid stems and white calcite veins have is exposed.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-Besa-001	10	613123	6069177	black shale with pyrite/marcasite nodules, Besa River Fm.
06-Besa-002	10	613276	6069106	black shale with pyrite/marcasite nodules, Besa River Fm.
06-Besa-003	10	611345	6068924	fossiliferous limestone
06-Besa-004	10	611237	6069070	siltstone/shale, Palliser Fm.

Site Name: Muskiki Formation
NTS: 93I 14
UTM: Zone 10 656199E – 658362E, 6078411N – 6081845N
Physiographic Area: Rocky Mountain Foothills
Reason for Concern: Permissive geology

Regional Geology: Minnes Group, Fort St. John Group, Smokey Group
The proposed pipeline route passes into the Rocky Mountain Foothills around KP 580, east of Kinuseo Creek, where it follows the north side of the Kinuseo Creek valley to approximately KP 554, where it begins to follow the Red Willow River valley, south of the river. The area is underlain by the Jurassic to Cretaceous Minnes Group, and the

Upper Cretaceous Fort St. John and Smokey Groups. The Minnes Group consists of sandstone, siltstone and shale. The Fort St. John Group is sideritic shale. The Smokey Group consists of seven different formations that are a mixture of siltstone, sandstone, conglomerate, and shale. One of the seven, the Muskiki Formation, is described as dark grey pyritic shale and fine grained clastic rocks that is of potential ARD concern. It is flanked by coarse clastic sedimentary units of the Cardium Formation to the west, and the Marshy Bank Formation to the east. Outcrop is sparse in the river valleys.

Site Geology: Two sites were examined in cut blocks, one site nearly 3 km to the north, and a second site1 km to the south adjacent to the proposed alignment. The northern site was comprised of a subcrop of very fine-grained sandstone. According to government geological maps, this site should like within the Muskiki Formation. No black shales were observed, as these are probably recessive weathering.

The southern site is in the Cardium Formation near its contact with the Muskiki Formation, though the contact is not exposed. Several low glacially striated outcrops of medium grained, immature sandstone are exposed in a clear cut block. The sandstone is composed of angular quartz-feldspar fragments, minor mica and 10% dark grains. It is olive-gray and slightly rusty weathering with no apparent bedding. A second outcrop of sandstone is finer-grained, more pinkish and not rusty weathering.

Sample Descriptions:

Sample No.	UTM Zone	Easting	Northing	Comments
06-MuskN-001	10	656199	6081737	sandstone outcrop on forestry road
06-MuskN-002	10	656423	6081845	siltstone with pebble clasts
06-Smokey-001	10	658362	6078411	immature sandstone

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APPENDIX B2

Photo 1. Kitimat Terminal Area – The oldest phase of intrusion exposed in the Kitimat Terminal area, is a mafic rock, which is cut by progressively younger and more felsic dykes. Note large white dyke in the center of the image. Localized quartz-pyrite veins are rusty weathering, visible to the right of the right hand figure.

Photo 2. Kitimat Terminal Area – Left: Detail of the vein in the previous image. Veins are present in the older phases of the intrusion.

Photo 3. Kitimat Terminal Area – Right: Close up view of the quartz vein with coarse-grained clots of pyrite crystals. As is evident from these photos, these veins are susceptible to oxidation when exposed to atmospheric conditions.

Photo 4. West Side of Lower Kitimat Valley – There are localized areas of rusty weathering intrusive rocks in outcrops north of the Kitimat Terminal site. The staining is due to the presence of pyritic veinlets.

Photo 5. West Side of Lower Kitimat Valley – A faulted contact between intrusive rocks of the Poison Pluton and Telkwa Formation volcanic rocks is exposed along the roadway, opposite the Alcan Plant. Both rock types are pervasively chlorite altered. Epidote alteration occurs in veinlets, and reddish hematite occurs on fracture surfaces. A minor amount of pyrite is present as veinlets and finely disseminated in the wallrock.

Photo 6. "J" Showing – The "J" showing, a volcanogenic massive sulphide style occurrence is exposed on the south-west bank of the Wedeene River, beneath a railway bridge. Telkwa Formation volcanic rocks are overlain by a granodiorite body. The volcanic rock is pervasively chlorite altered, and there are quartz-epidote-chlorite-calcite veinlets at the contact in both the volcanic rock and the granodiorite. Minor amounts of pyrite and chalcopyrite were observed disseminated in both rock types. There is rusty weathering on fractures.

Photo 7. Hoult Minfile – There are calcite-filled vesicles and minor amounts of disseminated pyrite visible in the rock.


Photo 8. Hoult Minfile – Left: Rusty weathering outcrop of volcanic rock upslope and to the west of the massive quartz-monzonite intrusion exposed in the clear cut.
Photo 9. Hoult Minfile – Right: Detail of the outcrop illustrating biotite/chlorite altered volcanic rock, cut by a white quartz vein. The rusty weathering is due to sulphides associated with these veins.


Photo 10. Hoult Minfile – Left: The volcanic rocks are in contact with a large pale pink quartz monzonite intrusion. Clots of pyrite occur locally in the intrusion, though overall sulphide content is low.
Photo 11. Hoult Minfile – Right: Molybdenite is also present in the intrusion, associated with quartz veins, and as fracture coatings.

Photo 12. Hoult Minfile – Fine-grained porphyritic dykes cut both the volcanic rock and the quartz monzonite intrusion.

Photo 13. Hoult Minfile – Left: To the west of the Hoult Showing, just above an unnamed tributary of Hoult Creek a small zone of fault related intense clay-pyrite alteration is exposed in an outcrop of the intrusion.

Photo 14. Hoult Minfile – Right: Detail of alteration. Abundant fine-grained pyrite oxidizes to leave a friable rusty weathering outcrop.

 

Photo 15. Nimbus Ridge – Left: The ridge above the proposed eastern portal of the Hoult tunnel was examined. The area is surrounded by steep topography.
Photo 16. Nimbus Ridge – Right: Blue-green Cu-oxide stain was observed in outcrop below the ridge summit. Minor amounts of quartz veining, with associated disseminated pyrite were observed in fragmental volcanic rocks along the ridge top.

 

Photo 17. Ridge above Clore River canyon (North Hope Peak) – Left: This ridge drops steeply down to the Clore River 800 m below. The proposed pipeline route cuts through this ridge. Note helicopter for scale (right of center).
Photo 18. Ridge above Clore River canyon (North Hope Peak) – Right: The ridge is comprised of fragmental volcanic flows and crystal tuff, which grade up into flow banded rhyolite. Rusty weathering chlorite-magnetite veinlets are present in the rhyolite, and pyrite-pyrrhotite-chalcopyrite-magnetite veinlets occur at the fragmental volcanic/rhyolite contact.

 

Photo 19. North Hope Peak – Left: This is a view taken from the helicopter of the western flank of North Hope Peak. A large exposure of the North Hope Pluton is visible. It is cut by swarms of dark grey, steeply northeast dipping dykes. The intrusion weathers to a coarse grained sandy talus.
Photo 20. North Hope Peak – Right: The valley on the south side of the ridge is broad with shallow slopes. A meandering stream and associated marsh land and small lakes occur in the valley floor.

 

Photo 21. Burnie River – Left: Bedrock is exposed in steep banks above the Burnie River, just north of its confluence with the Clore River. Red Rose Formation sedimentary rocks include black shales, arkose and sandstones.
Photo 22. Burnie River – Right: The black shale was exposed on the east side of the river, and is cut by porphyritic dykes, with associated pyrite-sericite alteration. A sandstone/arkose with abundant white mica was exposed on the western bank of the river (not shown).


Photo 23. Telkwa Formation – Left: The area around the Morice River is underlain by Telkwa Formation, Skeena Group, and Kasalka Group volcanic and sedimentary rocks. Outcrop is very limited in this area and contacts between units are not visible. The sample site (06-Mor-001) is a ridge of outcrop in an otherwise overburden covered area. The rock is a polylithic fragmental volcanic rock with a maroon coloured hematite-rich matrix.
Photo 24. Telkwa Formation – Right: A large outcrop of volcanic flows with minor intercalated sediments was exposed adjacent to a logging road (06-Telk-001).


Photo 25. Telkwa Formation – Left: The basal units of this exposure are augite-phyric flows (in front to geologists), which grade up into hematitic lapilli tuffs, with silt/sandstone interbeds (rusty rocks). The tuffs are intensely fractured, with abundant calcite coated fractures and less common cross cutting calcite veins. There is a large apron of colluvium at the base of the cliffs, which has been cemented in place with calcite (ledge to the left of the geologists). Material from this exposure has been used for roadbed material.
Photo 26. Telkwa Formation – Right: Detail of the calcite cemented colluvium.

Photo 27. Silver Streak – Left: View of the landscape, looking southwest from the Silver Streak showing, towards Nadina Mountain. There is very little rock exposure in the broad valleys.
Photo 28. Silver Streak – Right: The site of the showing has been blasted and used for road fill. The rock in the pit was a fine-grained andesitic volcanic rock cut by opaline quartz and bladed calcite veins. It is rusty weathering, but no sulphides were observed.

Photo 29. Equity Silver Mine – Left: A prominent bluff to the northeast of the Equity Silver mine consists of a series of vesicular andesitic to basalt volcanic flows belonging to the Endako Group. The mine occurs in an erosional window in these rocks, which exposes older stratigraphy beneath, which is host to the mineralization.
Photo 30. Equity Silver Mine – Right: View from the same bluff. The mine occurs in the valley below, to the right, out of the field of view. The proposed pipeline route lies in the relatively flat low lying area, where there is very little outcrop.

Photo 31. Equity Silver Mine – View of the pit, now partially flooded, looking south.

Photo 32. Equity Silver Mine – View of the tailing facility, looking southeast.

 

Photo 33. Equity Silver Mine – Left: The Goosly intrusions are exposed in a borrow pit immediately southeast of the Equity Mine tailings dam. The pit is comprised of a series of dykes and possible flows of syenomonzonite(?) composition. The oldest unit in the pit is a fragmental volcanic, which is cut by brittle faults and numerous dykes with variable textures. Rusty weathering Fe-carbonate veins are abundant and cause the rusty staining visible in this photo.
Photo 34. Equity Silver Mine – Right: The dykes are glassy to porphyritic, and are characterized by platy white feldspar phenocrysts. Locally these phenocrysts comprise up to 50% of the rock, and are trachytic.

 

Photo 35. Equity Silver Mine – Left: The Endako Group flows are exposed in Foxy Creek, where the stream cuts down into them, forming a steep sided canyon. These exposures provide a view of the rocks that underlie the valley floor (06-Foxy-001).
Photo 36. Equity Silver Mine – Right: Away from the steep creek canyons, the topography is subdued, and there are very few outcrops exposed in clear cuts and logging roads.

Photo 37. Endako Group, Buck Creek Formation – Inter flow sedimentary units display graded bedded (06-Endak-002). Angular pebbles of volcanic rocks occur in a tuffaceous matrix.

Photo 37. Hanson Lake MINFILE – Top: The Hanson Lake showing itself was not located, however drill core was. Drill hole DDH-90-3 was collared in a white altered rhyolite dyke. (4.6-12.7m).

Photo 38. Hanson Lake MINFILE – Bottom: Cu-mineralization occurs in the amphibolite gneiss, which is cut by the rhyolite dykes. Sulphides are associated with quartz veins, and disseminated in the gneiss (22.2-29.0m).

Photo 39. Missinka – Left: The rocks are an alternating sequence pale silver-grey phyllite, and coarse grained schist, derived from mudstone/siltstones and quartz pebble conglomerates respectively. The phyllite is intensely foliated with three overprinting foliation fabrics developed.
Photo 40. Missinka – Right: Locally the primary bedding is still visible in the phyllite (very fine layering running across the rock surface).

Photo 41. Missinka – Left: Pyrite occurs as cubic porphyroblastic crystals disseminated in the phyllite. In this view, they have weathered out, leaving pits in the rock.

Photo 42. Missinka – Left: The phyllites are interbedded with a coarse grained quartz-muscovite schist, developed from a quartz pebble conglomerate. Sets of white quartz veins are preferentially developed in the schist. There do not appear to be any significant amount of sulphides associated with this veining.
Photo 43. Missinka – Right: Primary lithologic textures are locally preserved. In this view, a rip up clast of the mudstone/siltstone, which forms the phyllite, is visible within the schist/conglomerate. In the same outcrop a few meters over, there is transition to siltstone, in which bedding is well preserved, and the foliation is not as intensely developed.

Photo 44. Missinka – Left: Detail of the pebble conglomerate unit, which grades into a quartz-muscovite schist.
Photo 45. Missinka – Right: Detail of the bedding preserved in the siltstone/phyllite, with bedding defined by rusty weathered beds.


Photo 46. Miette – Left: The black shale is a fissile, rusty weathering rock. Pyrite occurs as porphyroblasts and with quartz veins. It is highly reactive when exposed at surface.
Photo 47. Miette – Right: Detail of a rusty weathered vein, with abundant cubic pyrite crystals. The crystals weather out leaving a pitted surface.


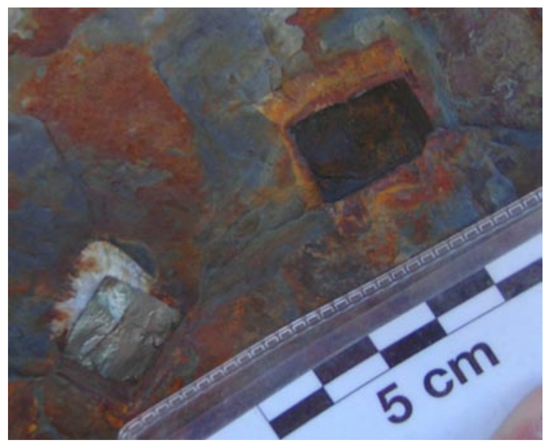

Photo 48. Miette – Left: White quartz veins cutting the shale, in a less intensely weathered outcrop.
Photo 49. Miette – Right: Detail of large pyrite porphyroblasts, with white quartz pressure shadows. The upper right hand crystal is completely weathered out.

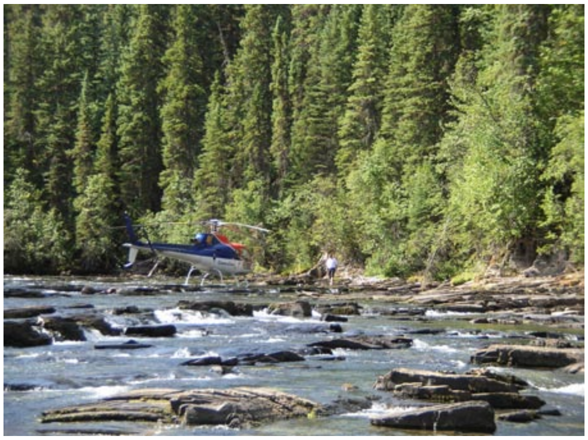


Photo 50. Besa River Formation – Left: The Besa River Formation is well exposed in Imperial Creek. In the creek the rocks are gently southwest dipping. The rocks are comprised of black pyritic shale, interbedded with dark grey-brown dolomite.

Photo 51. Besa River Formation – Right: On the banks of the creek the rocks are locally steeply upturned. Note the rusty weathering.


Photo 52. Besa River Formation – Left: Detail of a large (10 cm) pyrite/marcasite nodule. The rusty weathering is due to the presence of pyrite/marcasite nodules. These range in size from <1 cm to 30 cm in diameter.

Photo 53. Besa River Formation – Right: These nodules are highly reactive and are covered in a white sulfate precipitate which gives off a strong smell of sulphur. These precipitates are highly soluble.


Photo 54. Besa River Formation – Left: The shale is extremely fissile, breaking into mm thick sheets, which are coated in Fe-oxides and sulphates. The nodules weather out leaving rounded pits in the rock.

Photo 55. Besa River Formation – Right: The nodules are not pervasively distributed in the shale. They appear to be in restricted horizons, however because of the highly reactive nature of the nodules and the highly fractured nature of the rock, the rusty staining is pervasively developed on exposed surfaces.


Photo 56. Paliser Formation – Left: In a road cut along a ridge above Imperial Creek an outcrop of Paliser Formation limestone is exposed.

Photo 57. Paliser Formation – Right: The Paliser Formation limestone is fossiliferous, containing undeformed rugose and branching corals, bivalves, pieces of crinoid stems, with white calcite veins.

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Identification and Mitigation of Acid Rock Drainage and Metal Leaching During Construction, Enbridge Northern Gateway Project

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LIST OF ABBREVIATIONS

ABA	Acid Base Accounting
AMEC	AMEC Earth and Environmental, a Division of AMEC Americas Limited
AP	Acid Potential
ARD	Acid Rock Drainage
ARD/ML	Acid Rock Drainage and Metal Leaching
BC	British Columbia
BC MEMPR	British Columbia Ministry of Energy, Mines, and Petroleum Resources
BCGS	British Columbia Geological Survey
CCME	Canadian Council of Ministers of the Environment
Ck	Creek
Fm	Formation
GIS	Geographic Information System
Gp	Group
GSC	Geologic Survey of Canada
HDPE	High-Density Polyethylene
ICP	Inductively Coupled Plasma Mass Spectrometry
KP	Kilometre Post
Lk	Lake
ML	Metal Leaching
MoT	Ministry of Transportation
NAD 83	North American Datum of 1983
NAG	Not Acid Generating
NGR	National Geochemical Reconnaissance
NNP	Net Neutralization Potential
NP	Neutralizing Potential
NPR	Net Potential Ratio
NW	Northwest
PAG	Potentially Acid Generating
PVC	Polyvinyl Chloride
Rev	Revision
RGS	Regional Geochemical Survey
RoW	Right of Way
SE	Southeast
SW	Southwest
WRA	Whole Rock Analysis
XRF	X-ray Fluorescence

GLOSSARY

Acid Base Accounting (ABA)	An analytical technique applied to mine wastes and geologic materials that determines the potential acidity from sulfur analysis versus the neutralization potential. It is used to predict the potential of that material to be acid producing or acid neutralizing.
Acid Potential (AP)	The ability of a rock or geologic material to produce acid leachates; may also be referred to as acid generation potential or AGP.
Acid Rock Drainage (ARD)	A low pH, metal-laden, sulfate-rich drainage that occurs during land disturbance where sulfur or metal sulfides are exposed to atmospheric conditions. It forms under natural conditions from the oxidation of sulfide minerals and where the acidity exceeds the alkalinity. Non-mining exposures, such as along highway road cuts, may produce similar drainage. Also known as acid mine drainage(AMD) when it originates from mining areas.
Inductively Coupled Plasma Mass Spectrometry (ICP)	A type of mass spectrometry that is highly sensitive and capable of the determination of a range of metals and several non-metals at concentrations below one part in 10^{12}. It is based on coupling together an inductively coupled plasma as a method of producing ions (ionization) with a mass spectrometer as a method of separating and detecting the ions. ICP is also capable of monitoring isotopic speciation for the ions of choice.
Metal Leaching (ML)	The process whereby acidic waters formed by sulphide oxidation may break down other metal-bearing minerals and cause the release of dissolved metals.
Net Neutralization Potential (NNP)	NNP = NP – AP. The first 20 kg $CaCO_3$/t of a sample is considered to be 'unavailable'. Any sample with an NNP less than 20 is considered to have no capacity for acid neutralization.
Net Potential Ratio (NPR)	The balance between acid production and neutralization is expressed as the ratio of neutralizing potential (NP) to acid potential (AP).
Neutralizing Potential (NP)	The amount of alkaline or basic material in rock or soil materials that is estimated by acid reaction followed by titration to determine the capability of neutralizing acid from exchangeable acidity or pyrite oxidation. May also be referred to as acid neutralization potential or ANP.
Whole rock analysis (WRA)	Determines the major element composition of a rock in terms of weight percent oxide via lithium metaborate fusion. WRA is a useful tool for determining rock type, and when used in conjunction with trace metals analysis, WRA can help to highlight concentrations of elevated metals.

IMPORTANT NOTICE

EXECUTIVE SUMMARY

Enbridge has proposed to build an oil pipeline across central British Columbia and Alberta from Bruderheim, northeast of Edmonton to Kitimat on the Pacific coast. The pipeline will consist of a 914 mm diameter (NPS 36), pipe that will transport 83,400 m3/d (525,000 bbl/d) of oil per day from Bruderheim to Kitimat, and a second 508 mm diameter (NPS 20) diameter pipe that will transport approximately 30,700 m3/d (193,000 bbl/d) of condensate in the opposite direction from Kitimat to Bruderheim. Construction of the pipelines will also require the construction of a marine terminal, tankage, pumping stations, two tunnels and related facilities and infrastructure.

Construction of the pipelines will result in the excavation or exposure of bedrock in some sections, including locations for support facilities. A potential concern raised by Enbridge is that the excavation or exposure of potentially acid generating (PAG) bedrock along the pipeline route could potentially result in the formation of acid rock drainage (ARD). ARD can produce acidic, metal-rich water that can negatively impact receiving environments, especially streams, rivers and lakes.

During pipeline construction there are numerous processes that disturb the ground surface including trenching, grade exposure and excavation, directional drilling and tunnelling. Exposing, excavating or re-using rock can increase the likelihood of ARD and the associated metal leaching (ML) in sulphide-bearing rock due to increased interaction with water and oxygen and larger surface areas relative to the undisturbed rock.

Successful ARD management along the pipeline RoW will minimize environmental impacts without unwarranted escalation in financial costs to the project. ARD management along the RoW will follow the guiding principles of: 1) identification; 2) assessment; 3) avoidance where possible; 4) prevention where possible; 5) mitigation, and; 6) management.

Avoidance is the best PAG waste management option; however, it is not always possible. Selection of mitigation methods for each PAG section of the RoW requires consideration of what methods are geochemically appropriate, the work space and construction schedule requirements and the construction method. From a geochemical point of view, acid generation can be controlled by regulating one or more of the reaction components: sulphide minerals (such as pyrite), oxygen and water. Typical mitigation measures include blending with a non-PAG material, underwater storage, covers, water diversion, and/or collection and treatment of acid drainage.

ARD assessment of excavated or exposed rock will begin with a visual inspection of the outcrop for indicators of acid drainage potential by a designated person. Designated persons will be trained in the visual assessment of rocks for the presence of pyrite or other indicators of PAG rock as well as the selection of an appropriate mitigation method from the standard ARD mitigation strategies. If no pyrite or other signs of PAG rock are noted, then construction will proceed unhindered. If the rock is determined to be PAG, then an appropriate mitigation strategy will also be chosen, applied, and construction will proceed. If no appropriate mitigation strategy is identified, then the rock will be stockpiled on or near the RoW and additional assessment will be completed.

1.0 INTRODUCTION

Enbridge has proposed to build an oil pipeline across central British Columbia and Alberta from Bruderheim, northeast of Edmonton to Kitimat on the Pacific coast. The pipeline will consist of a 914 mm diameter (NPS 36), pipe that will transport 83,400 m3/d (525,000 bbl/d) of oil per day from Bruderheim to Kitimat, and a second 508 mm diameter (NPS 20) diameter pipe that will transport approximately 30,700 m3/d (193,000 bbl/d) of condensate in the opposite direction from Kitimat to Bruderheim. Construction of the pipelines will also require the construction of a marine terminal, tankage, pumping stations, two tunnels and related facilities and infrastructure.

Under the proposed project plan, the pipes will be placed in adjacent trenches or the same trench and covered with excavated material. In local areas, tunnels or aboveground structures will be used. Construction of the pipeline system will result in the excavation or exposure of bedrock in some sections, including locations for support facilities.

A potential concern raised by Enbridge is that the excavation of bedrock along the pipeline route could potentially result in the formation of acid rock drainage (ARD). ARD can produce acidic, metal-rich water that can negatively impact receiving environments, especially streams, rivers and lakes.

The purpose of this document is the following:

- To present standardized management strategies that can be employed during the construction phase of the project to mitigate the potential for acid drainage ; and,

- To summarize our current understanding to date of the ARD issues along the proposed pipeline corridor.

Management strategies identified can be adapted as the Project proceeds through detailed design and engineering and into construction. During the phases of the project, further site specific knowledge of ARD potential is expected to be acquired and further mitigation strategies developed.

2.0 ACID ROCK DRAINAGE

2.1 Introduction to Acid Rock Drainage

Acid rock drainage (ARD) refers to the naturally-occurring acidic runoff generated when rocks containing reactive minerals called sulphides (primarily pyrite, FeS_2) are exposed to air and water in a process called oxidation. The process of oxidation causes pyrite to breakdown into its chemical components of iron and sulphur.

Acidic waters formed by sulphide oxidation may break down other metal-bearing minerals and cause the release of dissolved metals, a process referred to as metal leaching (ML). In some cases, metal leaching may occur under neutral pH conditions without the onset of acid rock drainage, though they more commonly occur together.

Acid rock drainage and metal leaching (ARD)[1] have the potential to impact the receiving environment, including aquatic organisms and wildlife. As such, activities that involve significant rock excavation that might trigger or accelerate ARD are of potential concern. Breaking up or exposing potentially acid generating (PAG) rock can accelerate ARD by increasing the surface area available for sulphide oxidation.

Three reactants must be present for acid to be produced: oxygen, water and sulphide minerals. Removal or reduction of oxygen or sulphide minerals has the potential to avoid initiation of ARD and/or reduce the severity of metal leaching.

Not all sulphide minerals contribute to acid rock drainage, and of the ones that do, not all of those contribute equally. Pyrite is the most common and abundant sulphide mineral, it oxidizes more rapidly than most sulphides and during weathering is capable of generating the most acidity per unit. As such, it has been identified as the primary control factor for potential ARD along the pipeline route. Pyrite has been reported in rocks of all types and ages, but is found often in sedimentary lithologies such as black shale and coal seams, and in metamorphic rocks where it may be either a primary or a secondary mineral. Pyrite is also frequently found in hydrothermal veins and as a minor component in igneous rocks.

The proposed pipeline crosses numerous northwest-southeast geological terranes within British Columbia and Alberta spanning the entire range of geologic environments favourable to pyrite formation. Rock types which may contain pyrite and sulphide mineralization are significantly less extensive in Alberta; those rock types that are potentially susceptible to ARD are generally confined to the Rocky Mountains.

Just as not all sulphide minerals generate equal amounts of acid, not all sulphide-bearing rocks are potentially acid generating. In some cases, the acid generated from the oxidation of sulphide minerals may be neutralized by reactions with acid-consuming minerals in the same rock. The ability of a particular rock to generate acidity is a function of the balance between acid producing minerals and acid consuming minerals. Though many common rock forming

[1] For convenience in this document, ARD/ML is simply referred to as ARD.

minerals are capable of neutralizing acid, the most important acid neutralizers are certain types of common carbonates because they react quickly and generally provide more acid neutralization potential per unit than other minerals. The balance between acid production and neutralization is expressed as the ratio of neutralizing potential (NP) to acid potential (AP), or NPR. AP and NP are determined by analytical testing of rock samples that are spatially and mineralogically representative of the overall rock unit of interest.

It is important to note that certain potentially deleterious elements may be liberated from the oxidation of sulphide minerals (e.g., zinc from sphalerite, arsenic from arsenopyrite, or selenium in pyrite associated with some coal seams), and may be present at elevated concentrations in neutral pH waters. Neutral pH metal leaching can occur even in the absence of acid drainage. Neutral pH metal leaching is generally only a concern if discharge is into a sensitive resource and/or with little dilution (Ministry of Energy and Mines, 1998).

2.2 ARD on Construction Engineering Projects

The most common source of acid rock drainage is the mining and management of sulphide rich rock from coal or metallic ore deposits. However, anywhere sulphides are excavated and exposed to water and oxygen, the potential for ARD exists. Although the majority of research and case studies on ARD prediction and management are from the mining industry, there is an emerging understanding of the potential impacts of ARD on engineering projects, especially linear projects such as road construction.

Five ARD case studies from construction projects are discussed below. Taken together the studies outline an ARD predictive testing program, mitigative measures taken to avoid or reduce ARD from construction and waste rock management activities and examples of the high cost associated with failing to identify potentially acid generating rock.

2.2.1 Highway 97C, Pennask Creek, British Columbia

Source: Environment Canada, 2004

Highway 97C, also known as the Okanagan Connector, links Merritt to Peachland, BC. A road cut through local altered and pyrite-bearing sedimentary rock was exposed in the late 1980s. As the ARD potential was not recognized during construction, no mitigation efforts were applied and subsequently acid drainage formed. Surface water passing over the exposed rock became acidic and metal bearing. Drainage then flowed into an unnamed creek and onward to Pennask Creek, an important fish-bearing stream.

In 2005, the BC Ministry of Transportation (MoT) faced ten criminal counts of violating the Fisheries Act in response to uncontrolled acid drainage entering Pennask Creek. The MoT pleaded guilty to two counts and was fined a total of $46,000. In addition to the fines, the MoT has continuing costs to control ARD through drainage collection and limestone lined ditches.
Treatment of drainage at the site was recently implemented to comply with water quality standards.

2.2.2 Vancouver Island Highway Project, Vancouver Island, British Columbia

Source: Morin, et. al., 2003.

The Vancouver Island Highway Project (VIHP) was a 250-km long highway improvement project undertaken in the late 1990s.

One specific river crossing, the Tsolum River, had historic ARD impact from the now-closed Washington Mine located approximately 15 km upstream. Government and environmental groups worked to considerably improve water quality and fish habitat in the river following mine closures. Recognizing the sensitive nature of this river crossing, VIHP undertook a predictive ARD program.

ARD test results indicated that over half of the rock along the studied Tsolum River section of highway was potentially acid generating due to a reactive form of disseminated pyrite. A second round of test work indicated that there was a delay following exposure and the onset of acid drainage. The lag time was sufficient for excavation work and application of mitigative strategies prior to acid generation.

Based on the predictive ARD study, the highway alignment was shifted laterally and vertically to minimize the volume of disturbed potentially acid generating (PAG) rock. Avoidance was not possible for all PAG rock, necessitating additional mitigation strategies. To the extent possible, excavated PAG rock was encapsulated in the highway as fill enveloped in low permeability local till and topped with asphalt. Where PAG was exposed in rock cuts, surface water was diverted from the rock faces. Ditches at the base of rock cuts were lined with limestone and fed into a series of ponds, where water quality is monitored and could be treated if necessary.

2.2.3 Sea to Sky Highway Expansion, Horseshoe Bay to Squamish, British Columbia

Source: Golder, 2003a, 2003b, 2003c.

This well documented project is the expansion of the Sea to Sky Highway 99 between Vancouver and Whistler, BC. Geological mapping and a predictive ARD program indicated the presence of sulphide minerals and PAG rock along sections of the highway corridor. Acid generating rock had previously been observed along sections of the highway. Numerous mitigative measures were considered for both excavated and exposed PAG rock.

Where possible efforts were made to avoid PAG rock or minimize road cuts but total avoidance was not possible given the numerous topographic, environmental and engineering constraints. Five ARD mitigation options were examined:

1. Reuse PAG material as an aggregate in the asphalt. Additional options were examined as the volume of suitable PAG material is likely to be greater than the demand of asphalt aggregate.
2. Encapsulate PAG rock in bulk fill similar to the Vancouver Island Highway Project. This option was dismissed primarily because of a lack of locally impermeable encapsulating material to cover the PAG rock. There are also space restrictions

along the highway alignment for collection and monitoring ponds needed to ensure the encapsulated fill does not become acidic or leach metals.

3. Co-mixing of PAG rock with limestone. The high cost of required rock crushing and handling, both PAG rock and limestone, needed and the uncertain long-term effectiveness led to the dismissal of co-mixing as a mitigation strategy.
4. On-land disposal at the Britannia Mine site. The benefit of using the Britannia Mine for disposal relates to the available PAG rock storage capacity and the operating ARD water treatment plant installed for the mine's remediation.
5. Ocean disposal. This strategy is regulated by the *Canadian Environmental Protection Act, 1999*. Environment Canada views ocean disposal as permissible only after evaluation of on-land options have been determined less environmentally preferred or practical.

For exposed PAG rock cuts, shotcrete covers were suggested to seal the rock faces from oxygen and water flow. If adequate space was available, surface run off from the cut faces would be collected and treated, if necessary, otherwise lime would be placed in a ditch at the base of the rock cuts.

2.2.4 US Route 22 Bypass, Mifflin County, Pennsylvania

Source: Smith, et. al., 2006.

During construction of the Highway 22 bypass by the Pennsylvania Department of Transportation exposed pyrite-bearing rock of the Marcellus Shale. The ARD potential of the rock was not identified during construction but only subsequent to the onset of acidic drainage.

Following the onset of ARD, as much of the shale exposure was excavated as possible. The excavated rock was mixed with lime, and placed in a limestone encapsulated dump. The remaining rock exposed on the road cut was coated with a paraffin derivative, PennzSuppress, to impede air and water entry into the sulphidic shale. Finally, horizontal borings were drilled to intercept and drain groundwater before it could contact the problematic shale.

2.2.5 I-99 Interstate, Centre Country, Pennsylvania

Source: Gold, et. al., 2006

Construction of the I-99 interstate in Pennsylvania required excavation of the Bald Eagle sandstone that had an average of 5% veins that contained sulphide minerals. Below a ten meter thick gossan (iron oxide "rusty" zone), highway construction exposed unweathered sulphidic rock on two large cut faces totalling approximately 40,000 m^2. Prior to recognition of acid generation, the sulphidic rock was also used as fill in at least 6 sites along an 8 mile (13 km) stretch and taken to three different waste rock dumps. Within three months, acidic run-off was noted ($pH<3$) and construction was delayed for more than two years.

The recently approved ARD clean up measures require that all movable PAG rock (rock that can be picked up, consolidated and transported) be taken to an engineered rock placement area after mixing with limestone kiln dust. The rock placement area is lined with two layers of a synthetic material. Any leachate will be collected and treated. Synthetic liners will cover the 'immovable' rock, such as the rock cut faces and PAG rock incorporated in the road-bed sub-base or as embankment fill. Ground and surface water will be monitored.

The estimated total cost to mitigate the unrecognized ARD nature of the rock is USD $50 Million.

3.0 PIPELINE CONSTRUCTION CONSIDERATIONS

3.1 Construction Schedule

There are five main steps in the construction of a pipeline, starting with the surveying and clearing of the right of way (RoW). This is followed by grading and where necessary blasting of rock outcrops. Next the pipeline trench is excavated, the pipeline is placed and the trench is backfilled. A cap or cover, known as a 'roach', may be constructed over the trench using excavated material to assist in shedding water from the pipeline trench. The final step is clean-up and restoration of the RoW including final ground and surface water control measures.

Once begun, the construction process typically proceeds rapidly and on occasion there may be little opportunity for ARD assessment or delay. However, there are likely to be discontinuities between surveying/clearing and grading as well as between grading and trench construction where an ARD assessment could be completed.

3.2 Bedrock Disturbance

During pipeline construction there are numerous processes that disturb the ground surface. Exposing, excavating or re-using rock can increase the likelihood of ARD in sulphide-bearing rock due to increased interaction with water and oxygen and larger surface areas relative to undisturbed rock. The following is a brief description of some possible processes that could disturb bedrock during construction.

3.2.1 Grade Construction

Grade construction is part of the pipeline right-of-way preparation, typically involving preparation of a more or less level and smooth working bench to facilitate construction. This graded bench is typically constructed by cutting, filling, or some combination of the two (cut and fill construction). Cut and fill is the process of using excavated soil or shot rock from topographic highs to build up topographic lows.

3.2.2 Quarry or Rock Borrow

There are many applications of quarried or borrowed rock material in the process of pipeline construction. All involve excavating and transporting in-situ rock for placement as fill, aggregate, or for erosion control. Construction of access roads and placement of rock on muskeg or other very soft, wet ground to provide stability for machinery may require excavated rock.

Dependant on local conditions, rock borrow may be needed to backfill the pipeline trench. Backfill material can use local or transported fill, with or without amendments to create suitable fill characteristics.

Another expected use of quarried or borrowed rock is for use as rip rap in stream or slope erosion control measures.

3.2.3 Other Excavations

Other construction processes that could expose sulphidic material include cuttings and exposed rock surfaces from tunnel construction and directional drilling.

3.2.4 Rock Exposures

In addition to excavation, pipeline construction will expose rock in the walls of the trench excavation, on cut faces required for grade construction or slope stability and in tunnel walls.

4.0 GUIDING PRINCIPLES IN ARD MANAGEMENT

Successful ARD management along the pipeline RoW will minimize environmental impacts without unwarranted escalation in financial costs to the project. ARD management along the RoW will follow the guiding principles established by Price and Errington (1998) in the publication '*Guidelines for Metal Leaching and Acid Rock Drainage at Minesites in British Columbia'*:

1. Identification
2. Assessment
3. Avoidance
4. Prevention
5. Mitigation
6. Management

These principles are based upon policies and approaches developed in British Columbia for the management of ARD at minesites. These principles were developed with the idea that it is possible to prevent ARD generation through prediction and design, avoiding long-term mitigation and risk (Price, Errington and Koyanagi, 1997).

Details of the six guiding principles are described below:

1. **Identification** – prior to construction potential ARD locations along the RoW will be identified through staged field sampling programs.

2. **Assessment** –any ARD sites identified along the RoW will be assessed using methods consistent with those used at other ARD sites to determine the possible impact upon the surrounding environment as a result of the pipeline construction. The initial assessment of potentially acid generating (PAG) material may be visual or using field-based analytical methods.

3. **Avoidance** – wherever possible the excavation or use of PAG rock will be avoided.

4. **Prevention** – during the construction phase, best practices and accepted methods will be employed to prevent the occurrence of ARD wherever possible.

5. **Mitigation** – if PAG materials are encountered during construction, mitigation of the site and materials will use the currently accepted best practice for ARD mitigation to minimize impacts on the surrounding environment.

6. **Management** – any ARD sites created as a result of the pipeline construction will be managed to minimize impacts to the surrounding environment.

4.1 Identification, Prediction and Avoidance

Identification of PAG materials is a staged process that begins with the inspection of geological materials for the presence of sulphide minerals. It is not possible to sample all rocks along the alignment that will be disturbed by pipeline construction, but using geographic information systems (GIS), and available Federal and Provincial geological databases combined with an understanding of geology, we can predict the locations most likely to encounter ARD. The current absence of naturally acidic conditions does not prove there will be no ARD in the future.

Identification and sampling of PAG material requires access to rock, and depends on the accurate identification of sulphide minerals, mainly pyrite, and buffering minerals which have diagnostic and easily recognizable characteristics. Other visual indicators of PAG material, exclusive of sulphide identification, include secondary iron or sulphate minerals as precipitates or accumulations on outcrops or in stream beds, and acid pH values in stream or other bodies of water. The opportunities for sample collection and testing are limited once pipeline construction begins, as outlined in the previous section. Identification of PAG material is also integral to the prediction of neutral metal leaching as sulphide minerals are the source of metals.

Prediction of the PAG capacity of a sample is based on laboratory testing and application of industry accepted criteria presented in the “Draft Manual of Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Minesites in British Columbia” (Price, 1997). Common test work includes acid base accounting, whole rock and metals analysis, and leach tests. Results from leach tests can indicate the presence of readily mobile elements under non-acidic conditions.

There are inherent difficulties in applying a single sample to represent the acid generating potential of a pipeline RoW segment. Prediction is generally much better controlled at a mine site where the sample density is often greater and the ARD results can be applied to discrete management units such as geological block models or bench heights. Greater uncertainties exist when extrapolating surface grab samples to pipeline RoW segments. The fundamental variability and heterogeneity of geological materials complicates prediction (Price, 1997).

Finally, the best prevention plan for ARD is avoidance of PAG rock. However, avoidance can only be applied to known PAG locations where realignment of the RoW is feasible. Avoidance was successfully applied on portions of the Vancouver Island Highway Project.

4.2 Management and Mitigation

Avoidance is the best PAG waste management option, however, it is not always possible to avoid all PAG material, especially as the RoW is oriented approximately perpendicular to the regional geological structures of British Columbia.

Management of PAG rock is required during the planning, construction and operational phases of a project. Proper management of PAG rock can reduce the required mitigation and minimize impacts associated with ARD. Selection of a mitigation method for each PAG section of the RoW requires consideration of what methods are geochemically appropriate, the work space and construction schedule requirements, the construction method and the timing of the work.

Acid generation can be controlled by regulating one or more of the reaction components; sulphide minerals (such as pyrite) and oxygen Typical mitigation measures include blending with a non-PAG material, underwater storage, covers, water diversion, and collection and treatment of acid drainage.

5.0 POTENTIAL ARD SOURCES

5.1 Known Occurrences of Acid Generating Rock near the RoW

A preliminary field investigation of the proposed pipeline alignment was completed in August, 2006. The approximate KP locations have been updated to the Rev R alignment during October 2009. Results are reported in the Draft Acid Rock Drainage and Metal Leaching Field Investigation (AMEC, 2006). Table 5.1 summarizes the known occurrences of PAG material near the current proposed RoW.

Table 5.1: Known Potential ARD Sites Along the RoW

Site	Approximate KP Location (Rev R)*	
	From	To
Kitimat Terminal (Proposed)	1172 (end of alignment)	includes all proposed Terminal facilities
Hoult MINFILE	1088	1089
Nimbus Ridge	1081	1082
Clore Ridge	1073	1079
Equity Silver and Foxy Creek	957	966
Misinchinka Gp	654	667
Miette Fm	637.5	647
Besa River Fm	601	605.5

* The kilometre point (KP) locations for these sites have been extrapolated in relation to the RoW and geology. The KP locations are not considered definitive boundaries.

Samples collected during the field program consisted of rock representing outcrops of suspect geological units. These samples often contained visible sulphides. Laboratory testing of these samples indicated that all samples determined to be PAG had visible sulphide minerals that were observed in the field. However, not every sample with visible sulphides was classified as PAG based on laboratory testing. This suggests the possibility of a false positive where material is PAG based on visual methods, and a low potential for false negatives where no sulphides are identified.

5.2 Potential Construction Sources of PAG Material

Once pipeline construction begins, there are numerous opportunities for PAG material to be exposed. Dependant on local conditions, any of these construction sources could occur at the known occurrences of acid generating rock outlined in Table 5.1. Table 5.2 details potential ARD concerns for each potential construction source.

Table 5.2 Potential PAG Material Sources from Construction Processes

Source	Description	ARD Concerns
Trenches	Primary method for placement of pipeline. Linear feature excavated in overburden and rock (blasting maybe required for certain geological conditions)	• Represents the most extensive excavation method along RoW. • Limited ARD concerns if the trench is placed in overburden. • Trenches will be excavated and pipeline emplaced relatively quickly; time for ARD assessment is limited.
Grade Construction	Cuts for RoW construction, tunnel portals or other facilities. Excavated materials placed in low areas and/or used to backfill cut (cut and fill construction). Development of construction access roads to the RoW grade. Excavation and grade construction for Kitimat terminal and other facilities	• Compared to trenches, a large volume of material is excavated per unit length of pipeline. However, rock cuts will only occupy short sections along the overall pipeline. • Surface area of cut faces and exposed rock in the surface of the grade may be large and impossible to backfill/cover in steep sections. • Fill material may contain PAG rock.
Quarry / Borrow Pits	Construction materials obtained from nearby rock outcrops or surficial deposits.	• May contain PAG rock.
Stream Crossings	Directional drilling Conventional trench placement Aerial (elevated) crossing	• Directional drilling may encounter PAG rock unobserved from the surface requiring management of the drill cuttings and possibly exposed surfaces in hole. • PAG rock may be exposed adjacent to stream in conventional or foundations for aerial crossing. • Rip rap used for slope stability may contain PAG rock.

Source	Description	ARD Concerns
Tunnels	Two tunnels are planned for the RoW. Current plans call for disposal of the rock at or near the tunnel openings.	• Relatively large volumes of waste rock compared to other construction measures to be managed that may be PAG. • Interior surfaces may contain PAG rock: poor quality drainage may result.
Grade exposure	Rock hillside is exposed to create stable slopes.	• Expose large surfaces area of PAG rock to air and precipitation

6.0 ARD IDENTIFICATION STRATEGIES

6.1 ARD Assessment Process

As mentioned in Section 3.1, there are two main opportunities to asses the ARD potential of rock. The first opportunity occurs prior to pipeline construction when natural exposures of rock or drill core collected during the RoW assessment can be visually inspected and sampled. Sufficient time for detailed investigation of suspect materials is possible at this stage. The second opportunity for ARD assessment exists during the construction process. Initial grading and RoW clearing will likely expose additional rock outcrops that can be investigated, although less time would be available for analysis and interpretation. Additional rock outcrops and potential samples will be generated during drilling and blasting, excavation of grade rock and excavation of trenches in rock.

Figure 6.1 outlines a simplified process for ARD assessment once construction beings. The assessment utilizes visual inspection of the outcrop and drill cuttings at various stages of construction to initially assess the ARD potential of the rock. Identification of pyrite or other indicators of PAG rock will be carried out by a designated person responsible for PAG material identification. Designated persons with suitable backgrounds will be trained in the visual assessment of rocks for the presence of pyrite or other indicators of PAG rock as well as the selection of an appropriate mitigation method from the standard ARD mitigation strategies. If no pyrite or other signs of PAG rock are noted (including secondary iron or sulphate), then construction will proceed unhindered. If pyrite (or other indicators) are identified, one or more samples will be collected for total sulphur determination. A dedicated mobile analytical laboratory capable of fizz testing and using a Leco furnace for total sulphur analysis will be available to the project. If the total sulphur content is less than 0.1%, then construction should proceed. If the total sulphur content is greater than 0.1% but less than 0.3%, then fizz testing will be completed to indicate the presence of readily available NP. For material with sulphur content between 0.1% and 0.3% with a fizz rating of moderate or strong then construction should proceed. However, where the total sulphur content is between 0.1% and 0.3% and the fizz rating is none or slight, or if the total sulphur is greater than 0.3% then the area will be examined and sampled in more detail to determine the extent of PAG material An appropriate mitigation strategy will also be chosen and applied. If no appropriate mitigation strategy is identified, then the rock will be stockpiled on or near the RoW and additional assessment will be completed. Samples will be analysed at an accredited commercial laboratory to assess their ARD characteristics.

As a quality control check on this screening process, minimum of 2 samples per day should be submitted to an analytical laboratory to verify results of this screening process.

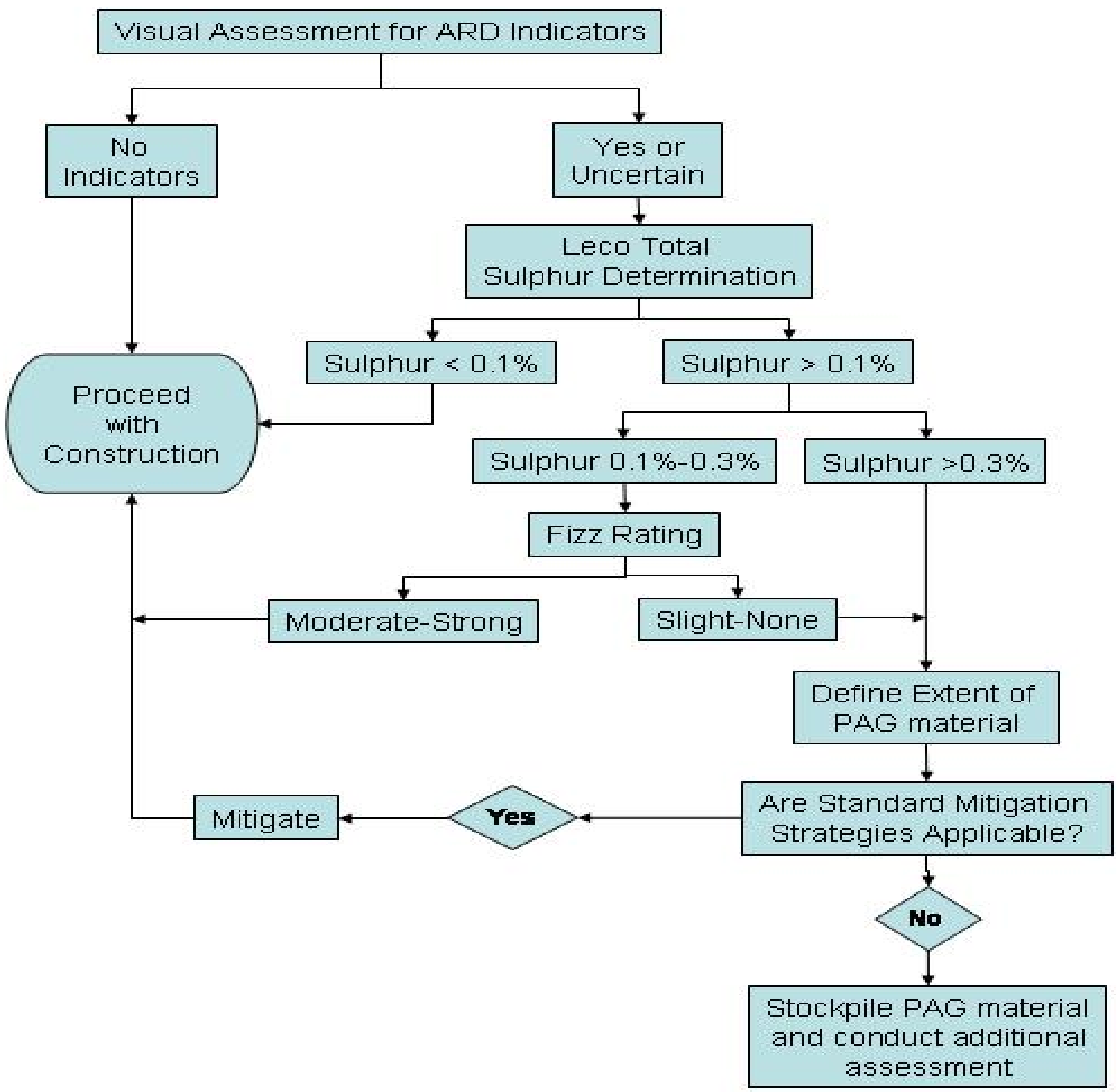
Note, that this assessment is exclusive of areas defined from previous work as known ARD sites. For known potential ARD sites, mitigation strategies will be developed prior to construction. It is beyond the scope of this document to recommend detailed, specific mitigation to known potential ARD sites along the RoW.

The most practical option for testing the ARD potential uses the services of a mobile field laboratory with a Leco Total Sulphur analyzer and the capacity to do fizz testing. Many commercial laboratories have the capability to setup and staff a mobile field laboratory. A mobile field laboratory can readily assess the total sulphur content of a material as a proxy to the sulphide content, and hence PAG classification of a sample.

The ARD assessment process would be the same for broken or exposed rock; although different mitigation measures are applicable for different construction methods.

It is expected that potential occurrences of neutral metal leaching will be associated with the presence of pyrite and other sulphides and will be identifiable using the same process as PAG rock. However, there is no predictive testwork that can be rapidly and easily completed during the construction process to determine the potential presence of neutral metal leaching. Areas where metal sulphides or coal beds are encountered should be recorded for post-construction inspection.

Figure 6.1: ARD Assessment Processes During Pipeline Construction



6.2 Rock Management During Assessment

It is possible there will be a delay between excavation or exposure of PAG rock and the application of a mitigation strategy, during which it will be necessary to manage the rock in a manner that does not impede construction progress or result in the release of ARD. Note that the interim management of PAG material is not considered a final mitigation strategy.

PAG rock may need to be segregated while awaiting assessment results and decision of final mitigation strategy. If space allows, segregating on or near the RoW workspace minimizes the cost of materials handling as the PAG material is dealt with near its source. Temporary mitigative measures such as a placement of PAG material in a lined storage facility and topped with a similar lined cover can be used to reduce the likelihood of developing ARD and releasing contaminated runoff.

Another option is to stockpile PAG material from several locations. This interim storage of PAG rock at an off-RoW location may be feasible in areas with limited work space. As with waste segregation on the RoW the nature of the PAG rock may dictate temporary mitigation measure to ensure no acid drainage or contaminated runoff is released into the environment. A suitable temporary repository would have to be identified or constructed.

7.0 MITGATION STRATEGIES FOR BROKEN ROCK

Common accepted mitigation strategies for PAG rock are avoidance, blending, covers, underwater storage, placement in a controlled repository, water diversion and water treatment. Selection of the most appropriate strategy will be dictated by the pipeline construction method, local conditions, the amount of work space for materials handling, availability of suitable PAG repositories, as well as the prevention of negative impacts to the environment. Wherever possible, the preferred mitigation strategies should not require long-term monitoring or water treatment. However, in some areas post-construction site inspections and monitoring may be necessary. Potential areas include suspect areas for neutral metal leaching or 'borderline' PAG materials.

7.1 Avoidance

The most effective mitigation strategy, and the first that should be considered, is avoidance (Price and Errington, 1998). Avoidance may not be practical for all ARD occurrences given the many environmental and engineering constraints of the pipeline. The general orientation of the geological units perpendicular to the RoW means that it could be difficult or impossible to avoid pyrite-bearing lithologies by shifting the alignment to the north or south. For some small mineralized showings with a limited volume of affected rock, minor realignments may be possible to avoid exposing the ARD occurrence.

7.2 Subaqueous Disposal

After avoidance, underwater disposal is generally considered to be the most effective strategy to prevent formation of ARD, as it essentially prevents oxidation of sulphide minerals and associated metal leaching. Underwater storage can be in fresh water or ocean water. Freshwater storage can be in natural or man-made facilities. Problems can arise with subaqueous disposal if PAG rock is allowed to oxidize prior to submersion and soluble oxidation products release stored acidity and/or metals when submerged. Underwater storage does not reduce the potential for PAG rock to generate acid or leach metals if the rocks are exposed in the future.

Many requirements must be completed before underwater disposal is allowed. There must be a detailed characterization of materials, identification of a suitable repository, hauling and placement of the PAG material to an off-RoW location, as well as numerous regulatory, environmental and engineering constraints to ensure that the PAG material remains submerged.

The Federal Fisheries Act governs the protection of fish and fish habitat in British Columbia prohibits waste disposal in natural, fish-bearing water bodies. Recently, approval has only been given for deposition in non-fish-bearing headwater lakes.

Ocean disposal of waste rock is regulated by the Canadian Environmental Protection Act 1999 and aims to prevent marine pollution from uncontrolled disposal of wastes at sea. The Disposal at Sea Regulation addresses disposal information requirements. Generally, all practical land-based options must be evaluated before an ocean disposal is considered.

Subaqueous disposal is not highly suited to a long, linear project like the Gateway pipeline since numerous facilities in remote and difficult to access areas with potentially long hauling distances would likely be required. However, for a few specific areas, potentially including sites such as the Kitimat Terminal or the tunnels, subaqueous disposal may be a viable option subject to further evaluation.

7.3 Covers

Covers are widely used to limit surface water and precipitation infiltration into PAG waste rock piles. Covers can also provide erosion control and growth strata for vegetation. Covers have been successfully used in many situations and are a practical ARD control measure.

There are several kinds of covers. Natural covers are generally made with locally available, low hydraulic conductivity materials, such as clay or glacial till. Covers can incorporate alkaline material, such as limestone (See Section 7.4 below), to further reduce the likelihood for the formation of acid drainage. Covers can consist of synthetic materials such as PVC or HDPE. Complex covers can integrate both natural and synthetic materials and may use layers of different characteristics to create capillary breaks, internal drainage or provide growth strata. Capillary breaks incorporated into complex covers have a compacted, low permeability layer interlayered with more permeable which serve as evaporation barriers. Capillary breaks have proven effective in excluding oxygen and precipitation from mine wastes and materials and are an effective ARD control agent.

Covers can be used on exposed rock faces, as well as waste rock piles. Shotcrete is commonly applied to the surface of exposed rock to reduce water flow and infiltration. Other types of covers, such as synthetic spray-on sealants may also be effective in certain circumstances where rock surfaces require isolation from water and oxygen.

Covers can potentially be integrated into the overall in the pipeline trench and roach design, applied to rock exposures, and used on waste rock piles both on or off the RoW.

7.4 Blending

Blending is the incorporation of PAG waste material with non-PAG waste material or an alkaline amendment such as limestone. Objectives in blending include the maintenance of neutral pH conditions and the in-situ neutralization of acidic drainage.

Blending works by either neutralizing the acid produced by PAG material during reactions with carbonate minerals or by using the alkalinity produced by carbonate mineral dissolution to neutralize acid. Blending does not eliminate acid generation but aims to create an overall neutral environment in waste rock piles or backfills. Blending does not prevent metal leaching

from alkaline or neutral drainage mobile elements such as zinc or molybdenum if the mineral sources for these elements are present.

Significant amounts of materials handling, potentially including crushing, are required to achieve an ideal blend where sulphides are in intimate contact with acid consuming materials, giving a homogenous, net-acid consuming mix. Acidity is neutralized immediately and migration of acidity and metals is limited.

Non-homogenous mixing can result in locally acidic conditions. Acid water produced locally can migrate away from the point of origin, but may be rapidly neutralized by contact with nearby carbonate minerals. Blending is considered less reliable than underwater storage (Price and Errington, 1998). However, it is more compatible to pipeline construction methods due to the extensive environmental and engineering requirements for underwater storage. Blending can be completed on the RoW using on-site equipment such as bulldozers or backhoes to mix limestone gravel or sand with PAG material prior to backfilling the trench.

With a large surplus of neutralization potential, small drainage inputs and/or low, neutral-pH metal loading, a blended waste may produce acceptable drainage for discharge. Non-PAG material can be sourced from local waste rock or alkaline amendments (limestone, lime or kiln lime). In addition to controlling ARD with an excess of alkalinity, other products such as pulp mill or organic materials can be applied to produce reducing conditions that may suppress ARD.

Ideal blending could be difficult to enact along the RoW given the limited work space. Layering or lining the pipeline trench with an excess of alkalinity (limestone) may be a reasonable mitigation measure where sulphides are identified. As well, limestone can be efficiently incorporated into the trench backfill or used as part of the cover material during roach construction. Addition of limestone would be determined on a site by site basis; however, as a minimum it is recommended to add sufficient limestone to achieve a 4:1 ratio of NP to AP in the material.

7.5 Disposal at an Existing Managed Site

Another mitigation option would be to evaluate the opportunities to dispose of PAG waste rock at existing disposal sites. This could include past producing mines such as Equity Silver or the Tumbler Ridge coal mining district (no ARD production, but several large water filled pits). It is likely not feasible that all PAG material could be disposed at one site given the large distances and difficult logistics of transportation along the RoW. There are also potential liability and ownership issues associated with this strategy.

7.6 Water Management

7.6.1 Diversions

Diversions are most effective to avoid mixing of pristine waters with potentially impacted waters or rock material and can be used with excavated and exposed rock. For exposed rock, surface water can be diverted around the cut face as was used at Highway 97 Pennask Creek, BC or

drain pipes can be installed to drain groundwater. Under certain circumstances, drainage channels could be lined with limestone to provide added neutralization capacity. However, these oxic limestone channels should be used with caution as they are prone to failure if not used properly. They are most effective used in combination with other mitigation methods and not as a stand alone method.

Within the pipeline trench, trench blocks can be used to keep groundwater or surface water infiltration flow from PAG or potential neutral metal leaching areas. Incorporating a low hydraulic conductivity cover into the roach and/or trench design that reduces water infiltration can also be considered as a water diversion.

7.6.2 Monitoring

Where PAG materials are encountered, or where neutral metal leaching may occur, it may be necessary to monitor the water quality. It is possible that monitoring may be required post-construction in locations where problematic rock has been identified. Simple measurements of pH and conductivity can indicate if acid drainage is developing. Metals analysis of seepages or stream flows can be used to indicate the occurrence of neutral leaching. Minor exposures of PAG rock may have no discernable influence on the water quality of nearby streams or water bodies.

7.6.3 Water Treatment Options

The objective of collection and treatment is to contain, neutralize and precipitate leached weathering products at a downstream location. Water treatment can involve simple passive treatment structures such as a settling pond, oxic limestone drainage trench or more complex structures such as a constructed wetland, or active water treatment using a lime treatment plant. Passive treatment may be the best strategy for marginally ARD impacted drainage in areas where more active treatment would result in a larger environmental impact (Price and Errington 1998). All treatment options must be designed for sustainability as they require varying degrees of long term financial commitment, monitoring and maintenance. Use of water treatment methods along the RoW would involve more detailed study that would likely be implemented following construction of the pipeline.

8.0 MITIGATION STRATEGIES FOR EXPOSED ROCK

Mitigation strategies for exposed rock are briefly covered in the previous section. Some strategies, such as blending, are not applicable to exposed slopes. Exposed PAG rock surfaces would most effectively mitigated by the use of covers, water diversion and passive water treatment.

9.0 EXAMPLES OF POSSIBLE MITIGATION STRATEGIES TO AREAS OF ARD

The following table provides examples of possible mitigation strategies that could be used along the RoW. The table provides a list of different scenarios where PAG rock could be excavated or exposed during pipeline construction (See Table 9.1). The possible mitigation strategies outlined are neither prescriptive nor associated with any particular section of the RoW. The possible strategies are measures that require a further evaluation to ensure compatibility with construction and local material constraints (i.e. local clay source for a natural cover or sufficient work space for construction of a passive water treatment wetland).

Table 9.1 Possible Mitigation Strategies During Pipeline Construction

Source	Description	Possible ARD Mitigation Strategies
Trenches	Primary method for placement of pipeline. Linear feature excavated in overburden and rock.	Blending of limestone sand/gravel with excavated PAG rock and emplacing mixture as trench backfill. Removal of excavated PAG rock to an external repository. Incorporation of glacial till or synthetic cover into trench backfill to reduce water infiltration. Use of trench blocks and drains to control/reduce water flow along the trench. Placement of shotcrete or synthetic spray-on cover on exposed PAG rock in trench walls to reduce water infiltration.
Grade Construction	RoW construction. Terminal Construction Portal construction Foundations for aerial crossings and other facilities.	Avoid using PAG rock in fill areas. Blending fine-grained limestone sand/gravel with excavated PAG rock and using as grade fill. Placement of shotcrete on exposed PAG rock on rock cuts. Surface water control and/or diversion. Offsite or onsite disposal of PAG rock using underwater methods, constructed cells or covers.
Quarry / Borrow Pits	Construction materials obtained from nearby rock outcrops or surficial deposits.	Avoid using PAG rock as construction material.\ Avoid exposures of PAG rock. Cover exposed PAG rock with till or limestone. Divert surface and ground water from exposed PAG rock.
Stream Crossings	Directional drilling	Blend PAG drill cuttings with limestone and place in trench adjacent to drill location. Removal of PAG drill cuttings to an external repository. Grout hole to cover exposed PAG rock in drill hole.
	Conventional trench placement	Removal of excavated PAG rock to an external repository. Blend PAG drill cuttings with limestone and place in trench adjacent to drill location.
	Aerial (elevated) crossing	Blend excavated PAG rock with limestone and place in trench outside of stream reach.

Source	Description	Possible ARD Mitigation Strategies
Tunnels	Two tunnels are planned for the RoW. Current plans call for disposal of the rock at or near the tunnel openings.	Cover exposed PAG rock in tunnel walls with shotcrete. Grout exposed PAG rock in tunnels walls to reduce water flow. Design and construct an oxic limestone channel and wetland as passive treatment for any PAG impacted water discharge. Removal of excavated PAG rock to an external repository. Blending of excavated PAG rock with limestone gravel and incorporation into covered tunnel waste rock pile. Dispose of PAG rock into a locally constructed underwater disposal area.
Grade exposure	Rock hillside is exposed to create stable slopes.	Placement of cover such as shotcrete on exposed PAG rock on rock cuts. Divert surface and ground water from exposed PAG rock.

10.0 LIMITATIONS AND CLOSURE

The findings and recommendations presented in this report are based on test results from samples collected during the Gateway Pipeline Field Investigation and office investigations using data bases compiled by others as noted in this report. Further planning and work to define potential ARD conditions should be undertaken during detailed engineering, design and construction.

This report was prepared exclusively for Enbridge Pipelines Inc. and their agents, for specific application to the proposed project as described in the report. The data and recommendations provided herein should not be used for any other purpose, or by any other parties. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. The findings and recommendations of this report were prepared in accordance with generally accepted professional scientific principles and practice. No other warranty, expressed or implied, is given.

This report was prepared under the supervision of Steve Sibbick, P.Geo. Senior in-house review was provided by Drum Cavers, P.Eng, P.Geo. External review was provided by Steve Day, P.Geo.. If you have any questions or comments regarding this work, please do not hesitate to contact the undersigned.

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PRELIMINARY GEOTECHNICAL REPORT ON PROPOSED COAST MOUNTAIN TUNNELS ROUTE (REV R KP 1072 TO KP 1087), ENBRIDGE NORTHERN GATEWAY PROJECT

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IMPORTANT NOTICE

This report was prepared exclusively for Northern Gateway Pipelines Inc. by AMEC Earth & Environmental Limited, a wholly owned subsidiary of AMEC. The quality of information, conclusions and estimates contained herein is consistent with the level of effort involved in AMEC services and based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions and qualifications set forth in this report. This report is intended to be used by Northern Gateway Pipelines Inc. only, subject to the terms and conditions of its contract with AMEC. Any other use of, or reliance on, this report by any third party is at that party's sole risk.

EXECUTIVE SUMMARY

AMEC Earth & Environmental has been retained by Northern Gateway Pipelines Inc. to provide geotechnical engineering services in support of the feasibility analysis and conceptual design of two utility tunnels through the Coast Mountains about 45 km northeast of Kitimat, BC.

The 6.5 km and 6.6 km long tunnels through North Hope Peak and Nimbus Mountain, respectively, would provide a low elevation route between the Clore River Valley (east) and Hoult Creek Valley (west) for the parallel crude oil and condensate pipelines of the Enbridge Northern Gateway Project between Rev R KP 1072 and 1087.

Geotechnical work to support analysis and design included:

- Site reconnaissance by various project members.
- Field data collection and mapping of detailed geology and surface rock structure data in the general project area along with geophysical investigations at select portal locations.
- Drilling investigations along select preliminary tunnel alignments and detailed laboratory logging and testing of core samples.
- Analysis of data related to several proposed tunnel routes.
- Development of a geological model for the area.

The Clore Tunnel and Hoult Tunnel alignments were selected from among four potential Clore routes and two potential Hoult routes based primarily on geotechnical conditions at the portal locations and the short surface route between the two tunnels.

The Clore Tunnel would be mostly located in the Telkwa Volcanics, which is a unit considered as favourable for advancement of tunnelling using TBM or drill and blast methods.

The Hoult Tunnel is mainly located in Bulkley Intrusives Plutonic Rock, which is considered to have a relatively high strength (estimate only) and favourable structure that will require relatively little support for TBM or drill and blast tunnelling.

1.0 INTRODUCTION

1.1 General

AMEC Earth & Environmental (AMEC) was retained by Northern Gateway Pipelines Inc. to provide geotechnical engineering discussion and recommendations to support the feasibility analysis and conceptual design of two proposed tunnels. The tunnels that would provide a low elevation route for crude oil and condensate pipelines of the Enbridge Northern Gateway Project through the Coast Mountains, about 45 km northeast of Kitimat, BC. This report presents the currently available results of the preliminary geotechnical investigation and assessment carried out by AMEC to date, including the selected tunnel routes.

The study area for this report is shown on Drawing 1.

Proposed site development plans (overall pipeline routing, tunnel alignment locations, and portal locations) were developed in conjunction with the Northern Gateway Pipelines Inc. civil engineering designer, WorleyParsons Calgary (formerly Colt Engineering).

1.2 Project and Location Overview

Two tunnels are planned along the project corridor where it crosses a section of high relief, alpine terrain through the Coast Mountains physiographic region. The overall 1172 km long twin pipeline project would include a crude oil export pipeline to transport crude oil from a terminal near Edmonton to an ocean shipping terminal at Kitimat and a condensate import pipeline that would carry condensate back to the Edmonton area terminal from Kitimat. The tunnels and interconnecting conventional pipeline route are intended to provide a safe, low elevation route for an approximately 15 km long portion of project corridor as follows:

- Clore Tunnel through North Hope Peak (local name, approximately Rev R KP1073 to KP1079).
- Conventional Pipeline Route (approximately Rev R KP1079 to KP1080).
- Hoult Tunnel through Nimbus Mountain (approximately Rev R KP1080 to KP1087).

1.3 Scope of Work

The purpose of the geotechnical work summarized in this report (carried out predominantly in 2006) was to collect geotechnical and geological information in support of geotechnical recommendations regarding a preferred tunnel route through the North Hope Peak - Nimbus Mountain corridor as well as the feasibility of the proposed tunnel construction from a geotechnical perspective. In general, the work included:

1. Initial discussions with respect to several proposed routes and the selection of the study area described in this report as the preferred alternative.

2. Field data collection and mapping of detailed geology and surface rock structure data in the area.
3. Selected drilling investigations along preliminary tunnel alignments.
4. Geophysical investigations at potential portal locations.
5. Geotechnical engineering analysis of data related to several proposed routes through the North Hope Peak-Nimbus Mountain corridor.

1.4 Project Corridor Description and General Tunnel Route Selection

The project corridor through the North Hope Peak and Nimbus Mountain area is part of the overall Rev R alignment into the upper reaches of the Clore Valley and the western approach through the Hoult Valley, as shown on Drawing 2. The regional area surrounding the project corridor is characterized by high relief terrain bounded by deeply incised creek and river valleys. Vertical relief is in the order of 1000 to 1500 m throughout the area, and a distinct pattern of northeast-southwest to northwest-southeast trending linear features including major watercourses and faults is noticeable on topographic maps and air photos.

North Hope Peak (local name) reaches an elevation of about 1660 m asl at its highest point and is rounded in shape with characteristic convex slopes. The mountain is bounded by the very steep Clore Canyon (local name) to the north (Photo 3), a low pass to the south, and very steep slopes adjacent to Hope Creek (local name) to the west (Photo 2). The very steep, cliff-like slopes along both the Clore Canyon and Hope Creek would make safe pipeline construction very difficult around the north or south sides of North Hope Peak, constraining the route to a tunnel through the mountain.

North Hope Peak and the eastern side of Nimbus Mountain are located adjacent to each other. The two areas are separated by the very steep, deeply incised valley containing Hope Creek (local name), which is a tributary to the Clore River, Copper (Zymoetz) River, and ultimately the Skeena River system. Photos 1, 4, 5, 7 and 8 show the area between North Hope Peak and Nimbus Mountain.

Nimbus Mountain (Hoult Tunnel area) reaches an elevation of about 2130 m asl at its highest point and is a sharp, jagged peak with steep slopes. The western side of Nimbus Mountain is located at the headwaters of Hoult Creek, a tributary of the Kitimat River system. A second tunnel through Nimbus Mountain was selected for the route due to the high relief, steep slopes, potential exposure to geohazards, and construction access difficulties. A conventional pipeline route was selected between the two tunnels (across Hope Creek). The general location of the Hoult Tunnel is primarily controlled by the Clore Tunnel location, as discussed in further detail in Section 4. Photo 6 shows the Hoult Creek area west of Nimbus Mountain.

Within the project corridor, the selected tunnel alignments through North Hope Peak and Nimbus Mountain were ultimately chosen from a set of four potential Clore Tunnel alignments

and two potential Hoult Tunnel alignments, as described in detail in Section 4. These tunnel alignments are shown on Drawing 2. The selected tunnel alignments are referred to as Clore Tunnel and Hoult Tunnel, while the previously considered tunnel alignments are named Clore Alternative 1, 2 and 3 and Hoult Alternative 1. The alternative tunnel alignments were chosen to review potential shorter routes, alternative portal locations and alternate pipeline routes across Hope Creek.

1.5 Background Information

1.5.1 Published Geological Information

A literature search and desktop study of the lithology and structural geology of the region was completed by AMEC. Although several general geology reports and maps were available for the region, very little detailed information was available for the area near the proposed tunnel locations. The available information consisted of a few mineral claim reports and limited mapping completed by both the Geological Survey of Canada and the British Columbia Geological Survey. Geological information for the purposes of engineering analysis is summarized in Section 3.

1.5.2 LiDAR

A 1 m resolution Digital Elevation Model (DEM) of portions of the project area generated from LiDAR data was provided by WorleyParsons Calgary (data from LiDAR surveys by Terra Remote Ltd.). Also provided was low-level aerial photography taken during the LiDAR surveys in 2006. Due to cloud cover during the survey period, portions of the highest elevation areas around Nimbus Mountain were not covered by the survey. The contour data from the DEM and aerial photographs are included as required on detailed drawings in this report.

2.0 FIELD PROGRAM AND TESTING

The field program (carried out in 2006) consisted of field reconnaissance and geological mapping of the project area as well as geotechnical drilling (including rock permeability testing) and geophysical investigations targeting specific features. The components of the field program and testing are described below.

2.1 Field Reconnaissance

Between March and October 2006, various representatives of the project team made site visits to the project area. Site reconnaissance trips were carried out to review alternate pipeline corridor routes, potential drilling targets, ongoing geological mapping, drilling progress, existing and new access road locations into the area, and approach and exit pipeline routes through the valley systems adjacent to the proposed tunnel route. The results of the field reconnaissance work are included in the text of this report.

The tunnel alternatives discussed in this report are all in the same vicinity. A regional reconnaissance of alternative tunnel routes over a much wider area was initially carried out.

2.2 Geological Mapping

An extensive geological mapping investigation was completed by the project team between April and August 2006 and in July 2009. A total of 49 days of helicopter-supported field mapping were used to map a region extending 3.5 km north of the junction of Clore River and Burnie River, and from the confluence of the two branches of Hoult Creek eastward to a point 15.5 km east of the upper Clore River. Ground-based examinations of several potential portal areas and tunnel alignments were completed as part of this work.

The results of the geological mapping, as well as logging and testing carried out on drill core are shown in plan on Drawing 2 as well as on tunnel cross section drawings (various). Note that some locations within the mapping area were not mapped for reasons of bear activity or difficult access on steep ground.

2.3 Drilling Program

Seven drill holes (DH06-#) were completed at the site between July and October 2006. The drilling originally planned for 2006 was to consist of 13 drill holes for a total length of 3622 m. Due to permitting delays, poor site access due to late season alpine weather conditions, and overall drill rig availability, the program was terminated prior to completion.

The completed drill holes were between 34 m and 714 m long, with a total drilled length of 2308 m. Core sizes varied from NQ to BQ depending on depth. H-casing was typically used in the upper parts of the holes. The drill holes were intended for characterization of the bedrock and groundwater conditions at depth along various potential tunnel alignments and for determination of the subsurface location, orientation and conditions of specific faults observed at surface.

Drilling was carried out by Geotech Drilling Services Ltd., of Prince George, BC, using rotary diamond drilling methods. Photos 1, 2 and 7 through 12 were taken during the drilling program. Helicopter-portable drill rigs were used due to the extremely remote nature of the drill hole locations throughout the site. A summary of the drill hole locations is provided in Table 2.1. Drill hole locations and projected traces are shown on Drawings 2 through 4.

Table 2.1: 2006 Drill Hole Summary

Hole Number	DH06-NH9	DH06-NH6	DH06-NW1	DH06-NH4	DH06-NS1	DH06-NH8	DH06-NH8A
Northing* (m)	6002061	6003929	6006816	6001936	6004809	6002518	
Easting* (m)	572753	570101	562904	575307	567406	571284	
Elevation* (m)	1300	910	765	1030	1385	1455	
Azimuth** (°)	60	120	0	0	54	60	240
Declination** (° from horizontal)	-58	-61	-90	-90	-62	-51	-51
Drill Location	North Hope Peak	North Hope Peak	Nimbus Mountain	North Hope Area	Nimbus Mountain	North Hope Peak	North Hope Peak
Target Area	North Hope Fault	West Portal Clore Alt 1	West Portal	East Portal	Nimbus Fault	Hope Fault	Hope Fault
Total Length (m)	674.1	34.4	50.3	187	714.1	64.9	583.4
Length in Overburden (m)	3	34.4	5.5	1	1.5	10.1	9.1
Length in Rock (m)	671.1	0	44.8	186	712.6	54.8	574.3
Piezometer (location, type)	n/a	n/a	n/a	n/a	289.6 m, RST Model VW2100	n/a	n/a

* Coordinates are NAD83 Zone 9U with elevations asl taken from the LiDAR DEM.
** Taken at drill hole collar

The drill core obtained at the site was sent to the AMEC laboratory in Edmonton, AB for detailed core logging, strength testing, and geochemical analysis. General stratigraphy intersected by the drill holes is summarized on the cross sections shown on Drawings 3 and 4.

2.4 Rock Permeability Testing

Packer testing was attempted with limited success during drilling. The intent of the work was to examine rock permeability conditions in potential fault zones identified in the geological mapping program. The tests were carried out at two drill holes, DH-NH8 and DH-NS1. Limited testing was conducted at the site, and it is believed that these tests were not carried out in the originally targeted fault zones due to challenges in testing in heavily fractured ground and at significant depths. The packer testing experienced limited success due to the extreme depth of the holes (greater than 500 meters) combined with the small diameter (BQ size, about 60 mm in diameter) in the testing zone.

A single successful test was completed on DH-NH8 between depths of 558 and 583 m. The test indicated a rock mass permeability of 8 x 10^{-8} m/s. This is an admittedly limited data set; however, the value is considered to be a reasonable estimate of rock mass permeability. Note that fault zones will likely have much higher permeability.

There was considerable variability in tunnel inflow estimates primarily due to uncertainty in permeability distributions including in the general rock mass as well as in the known faults. As first pass estimates, it is considered reasonable to use tunnel inflows near 500 L/s and instantaneous flows of 650 L/s or more. It is likely that hydrostatic pressures could be in the order of several hundred metres in some fault zones.

2.5 Geophysical Surveys

From October to November 2006, seismic refraction geophysical surveys were carried out at two potential portal sites: the east portal of the Hoult Alternative 1 tunnel option and the common west portal of the potential Hoult tunnel alignments. The geophysical surveying was carried out by Associated Mining Consultants Ltd. (AMCL), of Vancouver, BC. The objective of the work was to carry out surveys at all proposed portal areas; however, crew availability, permitting delays and ultimately poor weather (heavy snow) conditions forced early termination of the work in 2006 prior to completing the work.

3.0 GEOLOGICAL MODEL

The following summarizes the current geological understanding of the overall rock mass characteristics and fault zones that have been identified within North Hope Peak (Clore Tunnel) and Nimbus Mountain (Hoult Tunnel). Drawing 2 shows the overall site including geological units, the selected tunnel options, and previously considered tunnel options. For the purposes of defining design parameters, domains have been defined by lithology and have been subdivided further, as required, where significant changes in rock structure have been observed or inferred. A domain is defined as consisting of a portion of a rock mass where similar engineering or geologic characteristics have been identified. Note that a regional division was made at the valley system that divides North Hope Peak and Nimbus Mountain. This valley system occurs along what are interpreted to be major fault systems that have formed a significant topographic and geological boundary.

As indicated above, the rock mass domains have been defined on the basis of lithology (rock type) and rock structure; therefore, fault zones intersected by the tunnels have been defined as domains. Note that the domain length of the fault zones is defined as the total intersection length along the tunnel, calculated as a function of true width of the fault zone, diameter of the tunnel, and the intersection angle between the tunnel orientation and the fault trace.

For the purposes of discussion, all domains have been numbered from east to west along the tunnel alignments and the descriptions below are in that order. The domains are shown on the

geological cross sections (Drawings 3 and 4) by a number following the lithologic symbol (e.g. the Red Rose Formation domain is lKRs-101). The domain numbers do not repeat on the project. Given below are summaries of the domains within North Hope Peak and Nimbus Mountain. Detailed descriptions of these domains, including International Society for Rock Mechanics (ISRM) classifications of the rock units, are included in Appendix A.

3.1 North Hope Peak Domains (Clore Tunnel)

The lithological units expected to be encountered in the North Hope Peak area consist of volcanic and sedimentary rocks that pre-date the structural uplift and development of the Coast Mountains (pre-tectonic), and igneous plutonic rocks that were placed after the onset of major Coast Mountain building processes (post-tectonic). Some of the faults in the area apparently predate the placement of the plutonic rocks, and thus the conditions along the fault will depend on whether the fault is encountered in the post-tectonic plutonic rocks or in the pre-tectonic volcanic and sedimentary rocks.

The main discontinuity (joint) patterns appear to be associated with a post-tectonic stress regime and the joint patterns appear to be similar regardless of geologic age of the rock unit (with the possible exception of the sedimentary Red Rose Formation, described below). Three distinct joint sets are present throughout the area with occasional random sets. Of the three distinct sets, one set strikes northwest, one strikes northeast, and one is relatively flat. The northwest and northeast striking joint sets are consistent with the regional trend of northeast/northwest linear features mentioned in Section 1.4.

Faulting in the North Hope Peak area predominantly trends northwest-southeast with near-vertical dips. The faults in this area include the Clore Fault, North Hope Fault, Hope Fault, and Creek Fault. The fault domains are presented from east to west.

Summaries of the North Hope Peak domains which are expected to be intersected by the Clore Tunnel alignment are included in Table 3.1, below. The symbols used are those used on the geology map on Drawing 2 and on the cross section, Drawing 3.

Table 3.1: Summary of North Hope Peak Domains Intersected by Clore Tunnel

Domain Name	Domain Number	Brief Description	Tunnelling Considerations*
Telkwa Volcanics in North Hope Peak Area	IJT-104	Relatively competent volcanic rocks (meta-basalt and meta andesite flows with a possible occurrence of granodiorite plutonic rocks and rhyodacite flows at the eastern end). Contains andesite and basalt dykes 0.5 m to 10 m thick.	Considered a favourable rock unit for advancement of tunnelling using TBM or drill and blast methods.
North Hope Fault	Fnh-106	Cuts through all geological units in the North Hope Peak area. Trends northwest, sub-vertical, true thickness of 75 m (estimated) at the Clore Tunnel alignment.	Intersects the selected Clore Tunnel alignment at 40°, resulting in a total intersection length of about 123 m.
Closely Fractured Telkwa Volcanics	IJT-110	Highly fractured, veined Telkwa Volcanics.	Broken nature will increase bulk hydraulic conductivity and water storage in the rock mass, increase support requirements, and result in significantly slower average advance rates for drill and blast tunnelling or possibly TBM.
Creek Fault	Fck-111	Located on the western side of North Hope Peak. Trends north, sub-vertical, true thickness estimated up to 100 m.	Intersects the selected Clore Tunnel alignment at 60°, resulting in a total intersection length of about 59 m.
Colluvium & Soft Ground Conditions at Western Portals	Qs-cv-112	Significant colluvium and surficial deposits believed to exist at the western portal of the selected Clore Tunnel alignment. Thickness assumed to be at least 40 m perpendicular to the existing slope profile.	Soft ground tunnelling conditions expected.

*Note: General Considerations only. These do not constitute design conclusions.

3.2 Nimbus Mountain Region Domains (Hoult Tunnels)

The lithological units expected to be encountered in the Nimbus Mountain area include volcanic and plutonic rocks that were formed prior to, and after, the structural uplift and development of the Coast Mountains. The post-tectonic plutonic rocks in the Hoult Tunnel area are, however, older than the plutonic rocks in the Clore Tunnel area, which has implications with respect to some aspects of faulting and “random” joints.

While Telkwa Formation volcanic rocks are prominent on the geologic map shown on Drawing 2, the rocks at tunnel elevation are projected to be predominantly plutonic rocks (LKg) of the Bulkley Intrusives. The Telkwa Volcanics are projected, based on geologic mapping, to occur mainly at the east side of Nimbus Mountain. The nature and location of the buried contact between the two formations is not exposed since it is under a cap of Telkwa Volcanics, so it has been projected from limited surface mapping data. As the projection of plutonic rocks at depth has not been tested by drilling, actual rock conditions may vary substantially from those projected.

Less drilling information is presently available for the Nimbus Mountain area than for the North Hope Peak area discussed above. Furthermore, much of the rock projected to occur along the tunnel alignment is not exposed at the surface due to the cap of Telkwa Volcanics that occurs over much of the area.

The predominant joint systems are the three sets that are regionally present, although slightly rotated relative to the North Hope Peak area. These joints appear to have been formed by stress conditions acting on a rock mass containing pre-existing joints. The earlier joints form “random” joint sets that are generally expected to have a lower continuity than the more recent joints. Three distinct joint sets have been identified in the area along with two random sets. Of the three distinct sets, one set strikes northwest, one strikes northeast, and one is relatively flat. The northwest and northeast striking joint sets are consistent with the regional trend of northeast/northwest linear features mentioned in Section 1.4.

Similar to the North Hope Peak (Clore Tunnel) area, fault trends are approximately northwest in the Nimbus Mountain (Hoult Tunnel) area; however, no observed zones of intense fracturing parallel to the fault systems have been identified in the work to date. The main faults identified in the Hoult Tunnel area include Nimbus Fault, Gully Fault and South Fork Fault. Note that South Fork Fault is not anticipated to be intersected, and is not discussed further in this report.

Summaries of the Nimbus Mountain domains that are expected to be intersected by the Hoult Tunnel alignment are included in Table 3.2. The symbols are those used on the geology map on Drawing 2, and on the cross section, Drawing 4.

Table 3.2: Summary of Nimbus Mountain Domains Intersected by Hoult Tunnel

Domain Name	Domain Number	Brief Description	Tunnelling Considerations*
Telkwa Volcanics in Nimbus Mountain Area	IJT-201	Relatively intact fine-grained, igneous volcanic rocks (breccias and tuffs), typically defined as meta-andesite lithic tuff with some phyllitic partings. Contains andesite and basalt dykes 0.5 m to 10 m thick. Contains felsite dykes 5 m to 20 m thick subparallel to tunnel axes.	Considered a favourable rock unit for advancement of tunnelling using TBM or drill and blast methods.
Nimbus Fault	Fnb-203	Cuts through all geological units in the Nimbus Mountain area. Trends northwest, sub-vertical, true thickness estimated to be about 15 m.	Intersects the selected Hoult Tunnel alignment at a relative angle between about 30° and 35° from the tunnel heading, resulting in a total intersection length along a hypothetical 5 m circular tunnel of between 34 m and 40 m.
Bulkley Intrusives Plutonic Rock	Lkg-202	Massive, uniform, leucocratic, fine- to medium-grained, plutonic intrusive rock (typically meta-tonalite, meta-quartz diorite and meta-alaskite) that has undergone low-grade metamorphism resulting in increased strength. Contains andesite and basalt dykes 0.5 m to 10 m thick. Contains felsite dykes 5 m to 20 m thick subparallel to tunnel axes.	Unexplored at depth, considered to have a relatively high strength (estimate only) and favourable structure that will require little support for TBM or drill and blast tunnelling
Gully Fault	Fgl-205	Cuts through the geological units on the west side of the Nimbus Mountain Region. Trends northwest, sub-vertical, true thickness estimated to be about 3 m.	Intersects the selected Hoult Tunnel alignment at a relative angle of about 20° from the tunnel heading, resulting in a total intersection length along a hypothetical 5 m circular tunnel of about 24 m.
Colluvium & Soft Ground Conditions at Western Portals	Qs-cv-206	Significant depths of colluvium and surficial deposits believed to exist at the western portal of the selected Hoult Tunnel alignment. Thickness assumed to be at least 40 m perpendicular to the existing slope profile.	Soft ground tunnelling conditions expected.

*Note: General Considerations only. These do not constitute design conclusions.

4.0 TUNNEL ALIGNMENT SELECTION AND DETAILS

As described in Section 1.4, the project corridor and general tunnel route areas (North Hope Peak and Nimbus Mountain) have been selected based on a regional evaluation. Drawing 2 shows the overall routing.

Table 4.1 provides preliminary portal location coordinates and tunnel orientation details for the selected Clore Tunnel and Hoult Tunnel alignments.

Table 4.1: Clore and Hoult Tunnel Details

Tunnel Option	East Portal			West Portal			Tunnel Orientation		
	N*	E*	Elev* (m)	N*	E*	Elev* (m)	Length (m)	Azimuth** (deg)	Gradient***
Clore	6002546	575776	765	6004893	569735	761	6479	291	-0.1%
Hoult	6005484	569262	770	6006789	562745	680	6646	281	-1.4 %

* Coordinates are in metres, NAD83 Zone 9U with elevations asl taken from the LiDAR DEM.
** Azimuths are with respect to the UTM grid.
*** Positive gradient implies increasing elevation in direction of tunnel azimuth.

Details including reasons for selection, expected structural domains intersected along the alignment and portal conditions for the selected Clore and Hoult Tunnel routes are presented below. Geotechnical considerations are given in tabular form in Tables 4.2 and 4.3.

It must be noted that the viability of the selected Clore and Hoult Tunnels is based on assumed geological conditions for the rock mass in each area based on projected surface mapping data only. In the Clore area, this includes two significant fault zones (North Hope Fault and Creek Fault) that have not been investigated by drilling to date. In the Hoult area, this includes two fault zones (Nimbus Fault and Gully Fault), and a geology model that has not been checked by drilling investigation. The condition of the rock mass at depth, the conditions along the fault zones and the groundwater conditions are not completely known and could affect the choice of tunnel excavation method and duration of construction.

Table 4.2: Geotechnical Considerations – Clore Tunnel

Component	Comment	Geotechnical Considerations
Pipeline Route Near East Portal	• Feasible pipeline route.	• Good conditions.
East Portal 765 m Elev.	• Low rock fall concerns. • Low avalanche concerns. • Shallow overburden cover expected.	• Low potential for geotechnical difficulties at portal development. • No seasonal constraints for portal operations (avalanches). • **Overall:** Favourable portal site.
Tunnel	• Length: 6479 m. Slope 0.062% up to east. • Projected fault zones intersection length: 182 m. • Soft ground tunnelling at portals: 200 m. • Length through closely fractured rock: 730 m.	• Second-longest tunnel of the Clore options. • **Overall:** Longer tunnel option than Clore Alternative 2 or Clore Alternative 3 but other criteria drives selection.
West Portal 750 m Elev.	• Minimal rock fall potential (close to rock-fall shadow line from crest of highly fractured zone, but no rock-fall paths found during aerial reconnaissance). • No avalanche concerns (no defined avalanche paths). • Up to 70 m or more of colluvium expected along line of tunnel (no subsurface data).	• Expect soft ground portal development in deep colluvium. • **Overall:** Considered the best west portal option from a geotechnical point-of-view.
Pipeline Route Near West Portal	• Preferred Hoult Tunnel is northern route to avoid crossing avalanche chutes to south.	• **Overall**: Workable conditions from a geotechnical point-of-view.

Table 4.3: Geotechnical Considerations – Hoult Tunnel

Component	Comment	Geotechnical Considerations
Pipeline Route Near East Portal	• No major pipeline route considerations identified except for Hanging Valley Creek. • Works best with selected Clore Tunnel	• **Overall**: Good conditions.
East Portal 770 m Elev.	• No rock fall concerns. • No avalanche concerns. • Located in existing cutblock. • Surface bedrock exposures near portal site indicate minimal soil cover.	• Low potential for geotechnical difficulties at portal development. • No seasonal constraints for portal operations (avalanches). • **Overall:** Good portal site.
Tunnel	• Length: 6646 m. Slope 1.3% up to west. • Projected fault zones intersection length: 153 m • Soft ground tunnelling at portals: NONE • Length in deep cover: 2200 m	• Marginally longer than Hoult Alternative 1 option. • High stress conditions anticipated in areas of deep cover.
West Portal 680 m Elev. (Same portal for all options)	• Low rock fall potential, but close to areas of rock-fall. Needs to be further checked. • Low avalanche hazard but close to avalanche areas. Needs to be further checked. • Shallow overburden cover expected at portal.	• Portal development to occur on relatively steep slopes. • Portal location confined due to adjacent rock fall and avalanche areas.
Pipeline Route Near West Portal (Same for both options)	• Can potentially route pipeline a short upstream on Hoult Creek to improve Creek crossing. Good crossing available. • In close proximity to rock-fall and avalanche areas, but appears to be a suitable route, subject to further work.	• **Overall:** Workable route.

4.1 Clore Tunnel Details

Details of the Clore Tunnel alignment including reasons for selection, alignment, expected structural domains intersected and portal conditions are discussed in the following sections.

4.1.1 Clore Tunnel Selection

The selection of the Clore Tunnel alignment from four potential Clore options was driven primarily by the geological conditions at the west portal locations, the rock type at the east portal and the overall length of the options. The west portal of the Clore Tunnel is located on the western slopes of North Hope Peak in an area with relatively low rock fall potential, and outside of potential avalanche zones. Clore Alternatives 2 and 3 had portals in areas with high geological hazards as well as moderate to high hazards along the access and pipeline routes.

The location of the east portal for the Clore Tunnel was chosen to avoid intersection of the Red Rose Formation rocks which are encountered by the east portal for the other Clore tunnel options and to reduce the overall length of the tunnel. The location places the portal and subsequent tunnel in the Telkwa Volcanics bedrock units, which are preferred for tunnelling (compared to the Red Rose Formation) based on higher strength properties and a lower degree of jointing and fracturing (resulting in a lower support requirements and potentially more rapid tunnelling). The slopes above the portal are expected to have a low potential for hazards such as rock fall, avalanche, or slope failure, although it is near potential avalanche terrain. The location of the east portal for the Clore Tunnel also provides an approximately 500 m shorter tunnel than would be necessary if the east portal common to the other alternatives was used for the Clore Tunnel.

4.1.2 Clore Tunnel Alignment and Structural Domain Summary

A summary of the alignment of the selected Clore Tunnel is provided below, along with a summary of the expected structural domains along the tunnel. For the purposes of calculation of fault zone intersection lengths, a hypothetical 5 m diameter circular tunnel was used. Intersection lengths are presented as a total length and as a percentage of the corresponding tunnel length.

- The Clore Tunnel falls between the previously considered Clore Alternative 1 and 3 options in terms of length (6479 m) and azimuth (291°). It is slightly longer than Clore Alternative 2 with the same azimuth. The selected Clore Tunnel alignment has the lowest gradient of all previously considered Clore options (-0.062%).
- The tunnel intersects the North Hope Fault (Fnh-106) and the Creek Fault (Fck-111), for a total fault zone intersection length of 182 m (2.8%).
- The tunnel is mostly located in the Telkwa Volcanics (IJT-104) (5367 m, 82.8%).
- The tunnel intersects 730 m (11.3%) of Intensely Fractured and Veined Telkwa Volcanics (IJT-110). No drilling has been carried out in this unit, so the characteristics of this domain, and whether any hydrothermal alteration is present, are unknown.
- The tunnel intersects 200 m of (3.1%) of Colluvium and Soft Ground Conditions (Qs-cv-112) near the west portal.
- It is possible that the Clore Fault may be located near the east portal of this option.

4.1.3 Clore Tunnel Portal Conditions

Presented below are summaries of the proposed tunnel portals for the selected Clore Tunnel alignment with respect to anticipated overburden thickness, general anticipated geological conditions, and potential geohazards.

4.1.4 Clore Tunnel East Portal:

- This portal location is shown on Drawing 5.
- The underlying bedrock appears to be Telkwa Volcanics (IJT-104).
- For the purposes of discussion, overburden thickness has been assumed to be about 25 m, consisting of colluvium and possible appreciable thicknesses of glaciofluvial sediments.
- The portal is located near the toe of the Clore Valley slope on a narrow bench on the west side of the river.
- Appreciable seepage was observed coming out of the sediments at the portal location during reconnaissance.
- The portal location is not believed to have rock fall, stability or avalanche issues.

4.1.5 Clore Tunnel West Portal:

- This portal location is shown on Drawing 6.
- The underlying bedrock is closely fractured Telkwa Volcanics (lJT-110), overlain by colluvium (Qs-cv-112).
- For the purposes of discussion, overburden thickness has been assumed to be about 40 m, consisting of colluvium and till with possible glaciofluvial sediments. This is based on estimates taken from projected section data only, and is not based on geophysical or drilling investigation data.
- The portal has steep slopes above and moderate to gentle slopes below.
- The site is believed to have a minimal rock fall potential.

4.2 Hoult Tunnel Details

Details of the Hoult Tunnel alignment are presented below, including reasons for selection, alignment, structural domains intersected and portal conditions.

4.2.1 Hoult Tunnel Selection

As noted in Section 1.4, the selection of the Hoult Tunnel alignment from the two potential Hoult options was largely driven by the surface constraints and access conditions at the east portal, and by the choice of the preferred Clore Tunnel alignment. Specifically, use of Hoult Alternative 1 with the selected Clore Tunnel alignment would have required pipeline construction and consequent construction access and ongoing operations below two significant avalanche chutes near Hanging Valley Creek. A further advantage of this combination of tunnel options over the other combinations is that a single crossing of Hope Creek would be required. The area is in a logging cut block and has shallow soil cover, which is an advantage for portal construction.

4.2.2 Hoult Tunnel Alignment and Structural Domain Summary

A summary of the alignment of the selected Hoult Tunnel is provided below, along with a summary of the expected structural domains along the tunnel. For the purposes of calculation of fault zone intersection lengths, a hypothetical 5 m diameter circular tunnel was used. Intersection lengths are presented as a total length and as a percentage of the corresponding tunnel length.

- The Hoult Tunnel is slightly longer, more westerly trending, and has a slightly higher gradient than the than the previously considered Hoult Alternative 1 option, with a total length of 6646 m, an azimuth of 281°, and a gradient of -1.4% descending toward the west.
- The tunnel intersects the Nimbus Fault (Fnb-203), and the Gully Fault (Fgl-205), for a total fault zone intersection length of 64 m (1.0%).
- The tunnel is mainly located in the Bulkley Intrusives Plutonic Rock (LKg-202) (5172 m, 77.8%).
- Lesser portions of the tunnel intersect the Telkwa Volcanics (IJT-201) (1370 m, 20.6%).
- The west end of the tunnel intersects Colluvium and Soft Ground Conditions (Qs-cv-206) (40 m, 0.6%).

4.2.3 Hoult Tunnel Portal Conditions

Summaries of the proposed tunnel portal conditions for the selected Hoult Tunnel alignment are presented below, including anticipated overburden thickness, general anticipated geological conditions, and potential geohazards.

4.2.4 Hoult Tunnel East Portal

- This portal location is shown on Drawing 7.
- The underlying bedrock is undivided Telkwa Formation (IJT-201). It is assumed (but not proven) that the altered and fractured rock at the end of the Clore Tunnel across the valley is not present on the west side of Hope Creek.
- The anticipated overburden thickness is less than 5 m, consisting of colluvium and possibly minor till and glaciofluvial deposits. The overburden thickness was estimated on the basis of locally visible bedrock outcrops and nearby existing rock cuts.
- The portal is located on a moderate gradient slope in an existing logging cut block.
- No significant geohazards were identified at this site.

4.2.5 Hoult Tunnel West Portal

- This portal location is shown on Drawing 8.
- The underlying bedrock is Bulkley Intrusive Plutonic Rocks, LKg-202.
- The anticipated overburden thickness is 1 to 4 m, typically consisting of colluvium.
- The portal is located on a relatively steep gradient, forested slope on the west flank of Nimbus Mountain. Avalanche zones and rock fall areas are present north and south of the portal area, and may influence the location and operations of construction and permanent pipeline access routes into the portal area. The steep slopes above the portal location indicate a potential for rock fall hazards near the site.
- The portal is located above the north fork of Hoult Creek where the creek is confined to a steep gradient channel with a canyon eroded in bedrock.
- There are avalanche chutes east of the site, but only a minimal avalanche hazard at the site based on present information.
- In summary, the geohazards at this portal site include:
  - Low rock fall potential at direct portal site, but access is close to or within the shadow zones of rock fall and avalanche areas; and,
  - Low avalanche hazard at portal site.

4.3 Regional Access Roads

Three main FSR networks provide access to the east, central and western ends of the project. The east end of the project site (Clore Tunnel East Portal) is accessed by the Morice FSR network. The central portion of the project (Clore Tunnel West Portal, the conventional pipeline route between the tunnels, and Hoult Tunnel East Portal) are accessed by the Copper-Clore FSR network. The west end of the project (Hoult Tunnel West Portal) is accessed by the Upper Kitimat FSR network.

The Morice FSR network extends about 95 km south and west from Highway 16 at Houston, BC to its current end location west of Gosnell Creek. The conditions along the route have not been reviewed in detail with respect to road or bridge conditions or potential geological hazards; however, the road is known to cross areas of deep-seated sliding along portions of the Morice River. From an overview perspective, this route predominantly crosses gentle to moderate gradient terrain, and so has a low risk of encountering significant rock fall or avalanche areas. Winter snow conditions are anticipated to be heavy along this route, particularly where it extends west into the upper reaches of the Gosnell and Clore Valleys.

The Clore-Copper FSR network extends about 70 km south and east from Highway 16 about 5 km east of Terrace, BC. The road is located along the Copper and Clore Rivers, through steep valleys and rugged terrain. A significant amount of the Copper River portion of the route (~50%) is located along an existing gas pipeline corridor. The overall route contains several geological hazards that will require consideration during construction and long-term pipeline operations, including the potential for large rock avalanches, rock fall, soil and rock slides, inundation from high water in the Copper River, and lateral erosion of the Copper River

The Upper Kitimat-Hoult Creek FSR network extends east from Highway 37S (between Terrace and Kitimat, BC) for about 29 km to Hunter Creek, then about 10 km east up Hoult Creek to the end of the existing road in a cut block. The route follows the general pipeline route through the Upper Kitimat and Hoult Creek Valleys, typically crossing moderate to rugged terrain with frequent stream crossings and some areas with avalanche chutes and debris flows.

5.0 SEISMIC CONSIDERATIONS

Seismic hazards and accelerations are discussed in other reports including Atkinson (2009). Additional information including general information on seismic aspects is also provided in AMEC (2009). In general, seismic accelerations are not a major concern for tunnels, particularly such low accelerations as would be expected in this area. Slides and rock fall near the portals might be triggered if failure were imminent; however, the portals as located per discussion in this report have been selected to avoid such areas. Any stability considerations have already been considered under the overall portal selection process and would not significantly differ under seismic conditions.

6.0 CLOSURE

Recommendations and evaluations presented herein are based on preliminary data only and are considered for conceptual/preliminary consideration only. In general, detailed on-ground site investigations have not been done, and at several locations aspects of the geological conditions are based on projections of limited surface mapping data only that may not reflect conditions at depth. It is expected that further investigations will be undertaken for the areas discussed in this report during detailed engineering for design and construction. If conditions other than those reported are noted during subsequent phases of the project, AMEC Earth & Environmental should be notified and be given the opportunity to review and revise the current recommendations, if necessary.

This report has been prepared for the exclusive use of Northern Gateway Pipelines Inc. and its engineering team for specific application to the area within this report. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC Earth & Environmental accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. It has been prepared in accordance with generally accepted geotechnical engineering practices. No other warranty, expressed or implied, is made.

If you have any questions or require clarification please contact the undersigned.

Respectfully submitted,

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REFERENCES

AMEC Earth & Environmental Ltd. 2009. *Overall Geotechnical Report on the Pipeline Route Rev. R for the Proposed Enbridge Gateway Project*, *Bruderheim, Alberta to Kitimat, BC.* Prepared for Northern Gateway Pipelines Inc.

Atkinson, G.M. 2009. *Preliminary Seismic Evaluation of Proposed Enbridge Northern Gateway Pipelines Project*. Report prepared for AMEC Earth & Environmental.

Wyllie, D.C. and C.W. Mah. 2004. *Rock Slope Engineering, Civil and Mining, 4th Edition.* Spon Press. New York, NY.

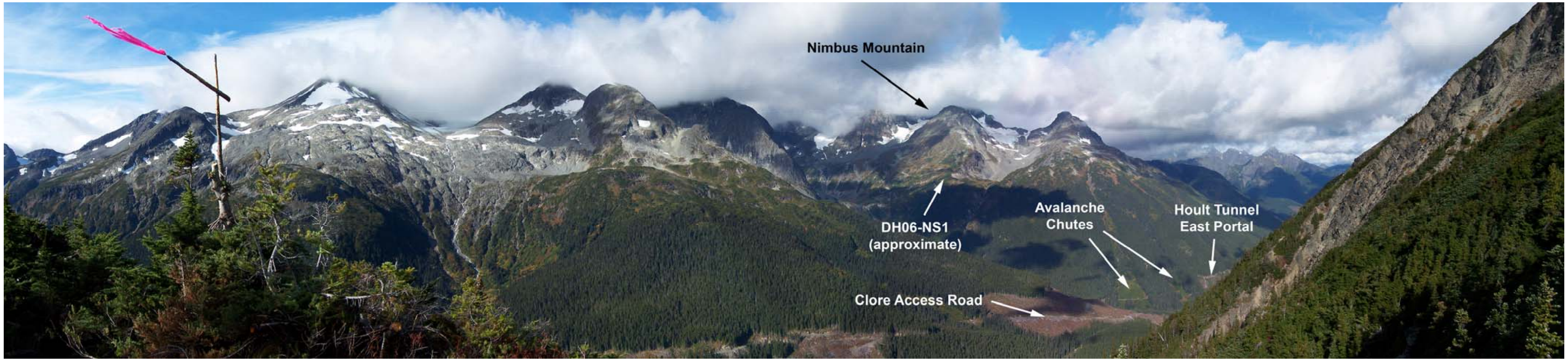

Photo 1: Eastern side of Nimbus Mountain viewed from western side of North Hope Peak.

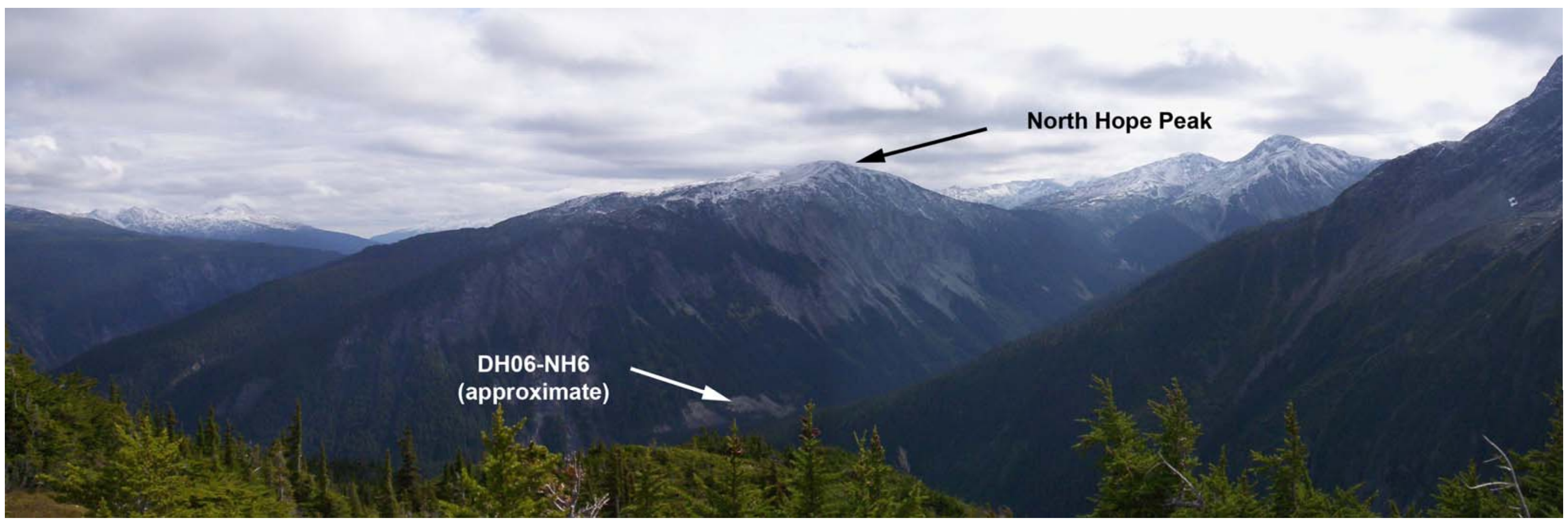

Photo 2: Western side of North Hope Peak viewed from eastern edge of Nimbus Mountain.

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ENBRIDGE NORTHERN GATEWAY PIPELINES

Preliminary Geotechnical Report on
Proposed Coast Mountain Tunnels Route
(Rev R KP 1072 to KP 1087)

NOTE: TO BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL REPORT ON COAST MOUNTAIN TUNNELS, DOCUMENT CONTROL NO. 1122-TR-20090519 DATED SEPTEMBER 9, 2009 .

DATE PREPARED: SEPTEMBER 2009

REVISION: 1

PREPARED BY: N.EKMAN / K.EKMAN/ S.HORSLEY

PROJECT No: EG0926008.2200

Photos 1 to 2

Taken: 2006

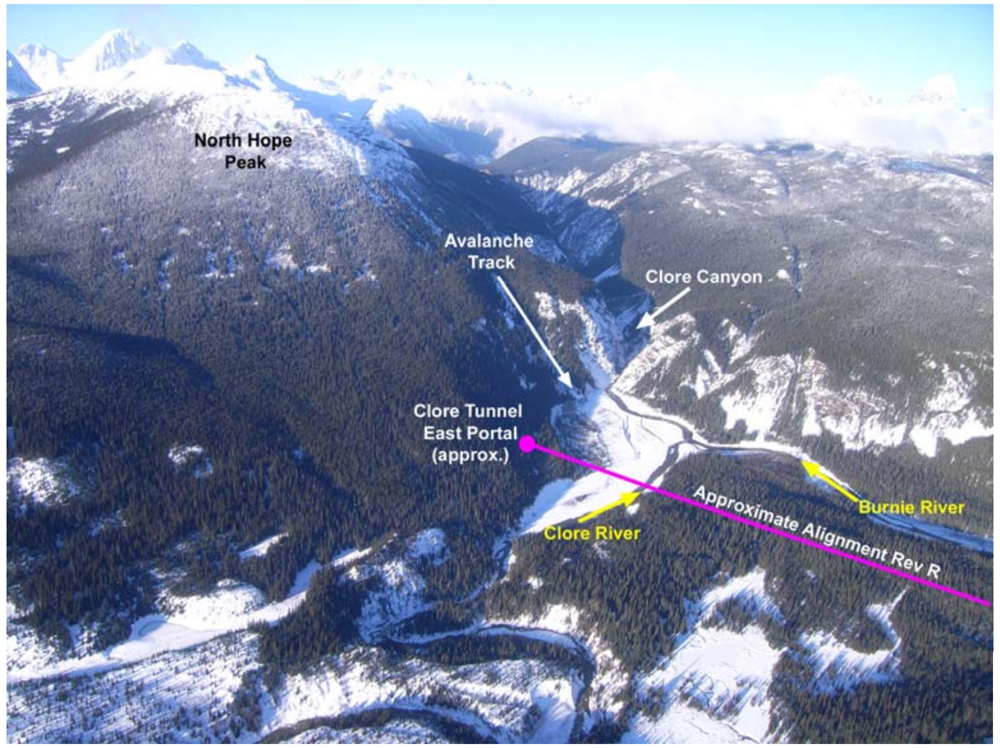

Photo 3: Looking northwest at the east side of North Hope Peak. Note the locations of Clore Tunnel East Portal and the Clore Canyon.

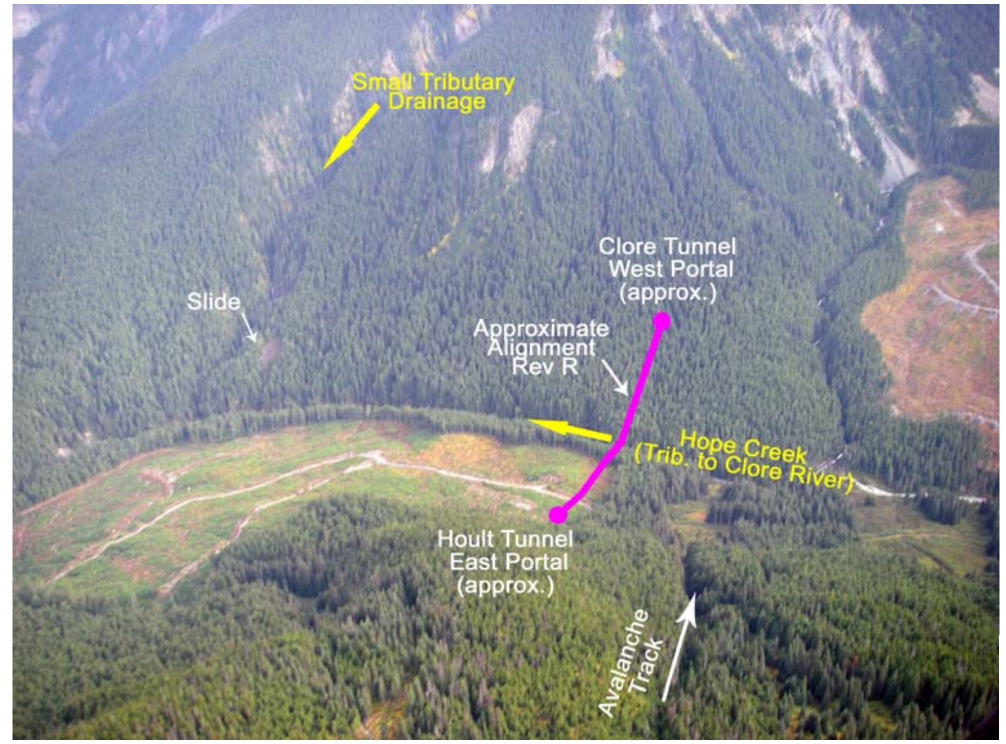

Photo 4: Looking south east from Nimbus Mountain at the proposed surface pipeline route between Clore Tunnel and Hoult Tunnel.

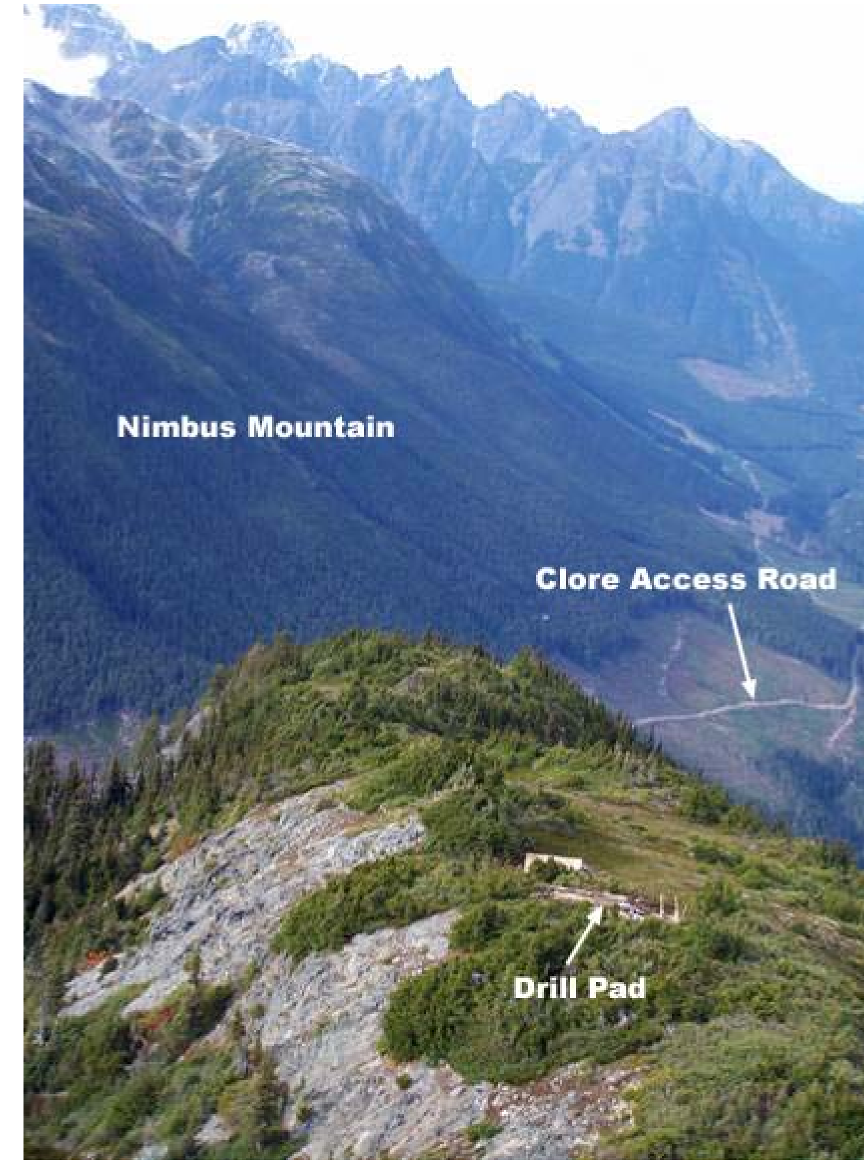

Photo 7: View of drill pad on North Hope Peak (hole was not drilled) showing Clore Access Road below and to the north.

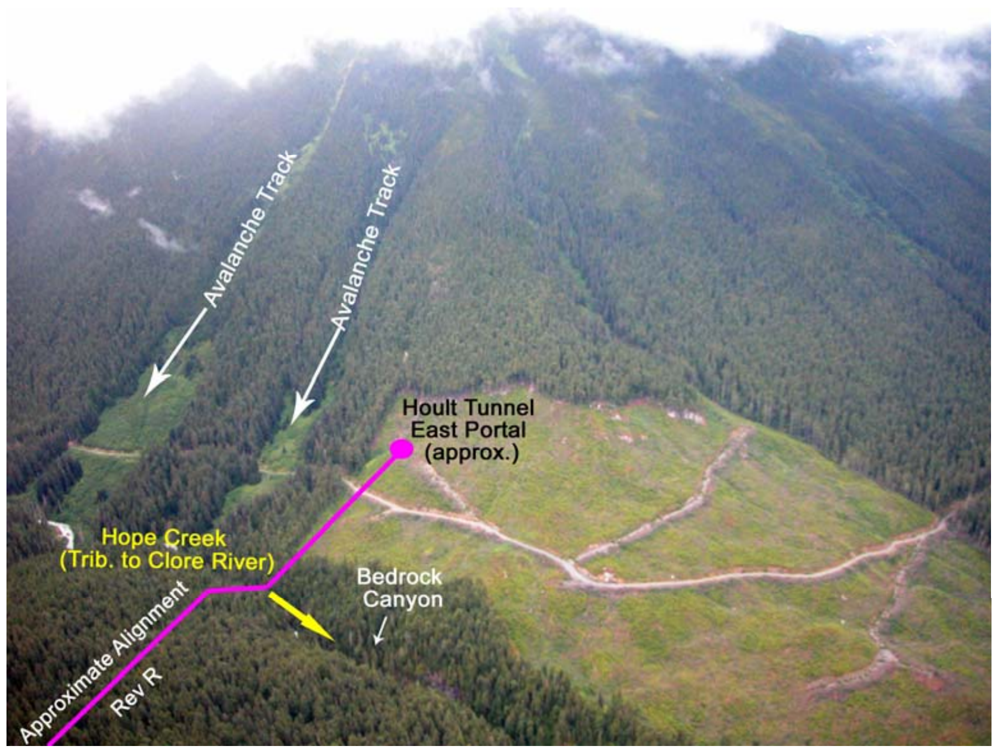

Photo 5: Looking northwest from North Hope Peak at Hoult Tunnel East Portal. Note the two avalanche tracks south of the pipeline route.

Photo 6: Looking northeast at Hoult Tunnel West Portal.

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ENBRIDGE NORTHERN GATEWAY PIPELINES

Preliminary Geotechnical Report on
Proposed Coast Mountain Tunnels Route
(Rev R KP 1072 to KP 1087)

NOTE: TO BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL REPORT ON COAST MOUNTAIN TUNNELS, DOCUMENT CONTROL NO. 1122-TR-20090519 DATED SEPTEMBER 9, 2009.

DATE PREPARED: SEPTEMBER 2009

REVISION: 1

PREPARED BY: K. EKMAN/ S.HORSLEY

PROJECT No: EG0926008.2200

Photos 3 to 7

Taken: 2006, 2008

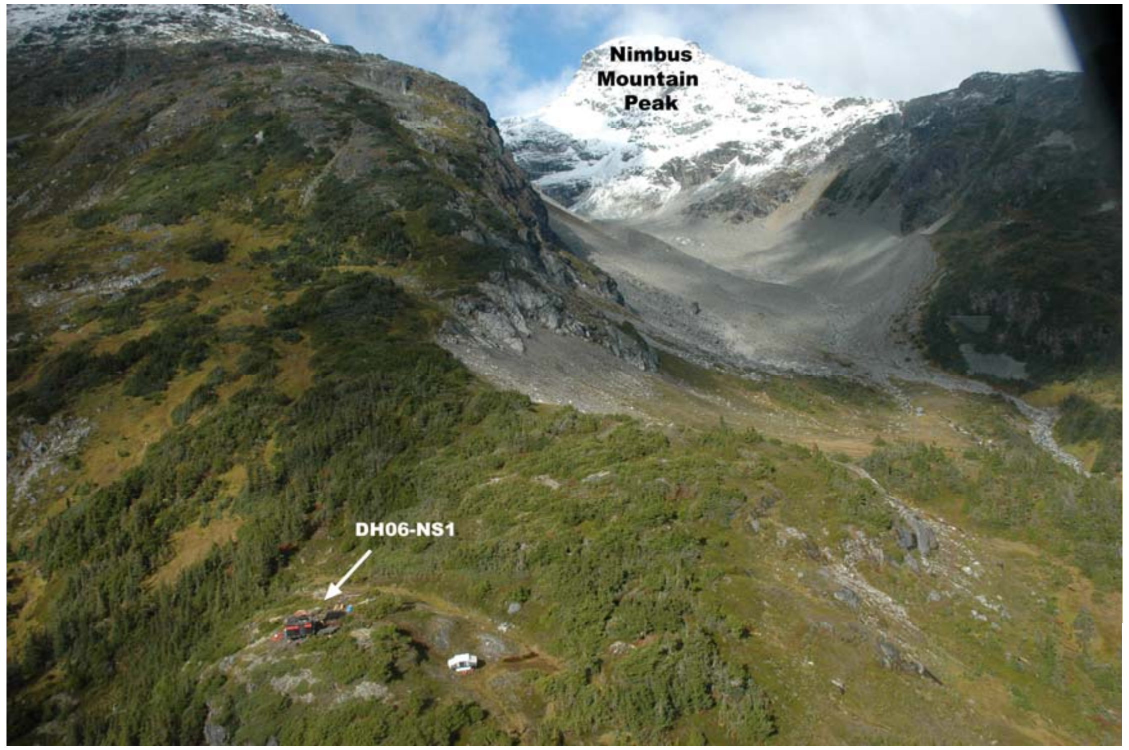

Photo 8: Looking west at the peak of Nimbus Mountain and the drilling set-up at DH06-NS1.

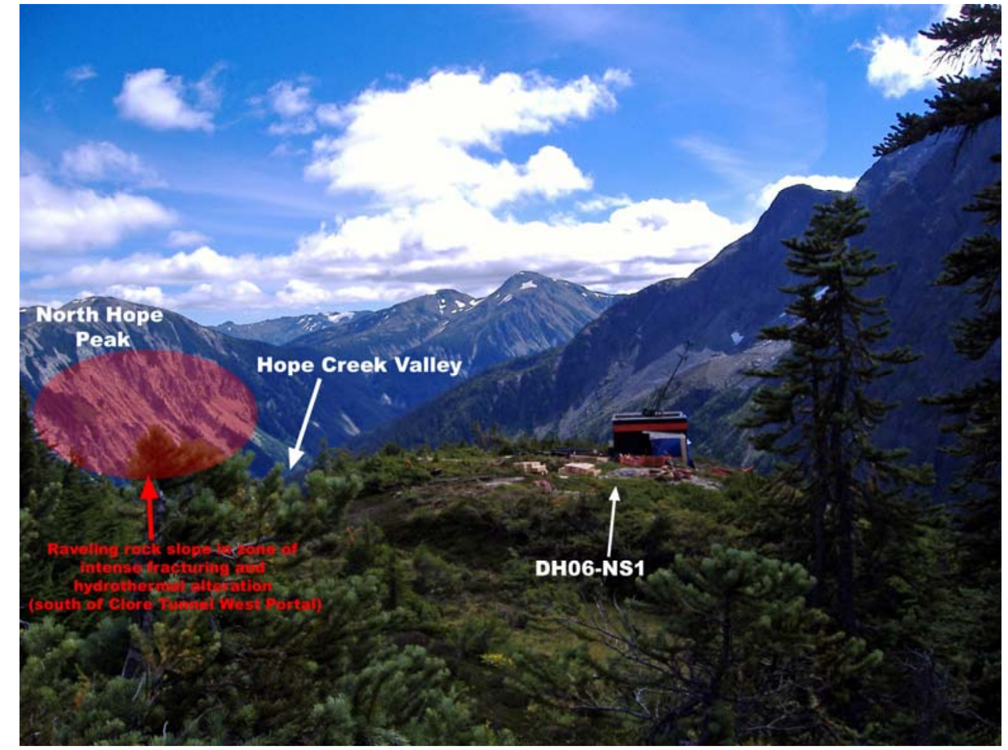

Photo 9: Looking southeast at DH06-NS1 on Nimbus Mountain. Note the raveling rock slope on the west side of North Hope Peak.

Photo 10: Approximately 2 metre long intact quartz monzonite core from DH06-NH9.

Photo 11: Broken/fractured core from DH06-NH8A

Photo 12: Helicopter-portable diamond drill set-up on North Hope Peak at DH06-NH9.

amec **AMEC Earth & Environmental** 2227 Douglas Road Burnaby, BC, CANADA, V5C 5A9 Tel. (604) 294-3811 Fax. (604) 294-4664	ENBRIDGE NORTHERN GATEWAY PIPELINES	Preliminary Geotechnical Report on Proposed Coast Mountain Tunnels Route (Rev R KP 1072 to KP 1087) NOTE: TO READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL REPORT ON COAST MOUNTAIN TUNNELS, DOCUMENT CONTROL NO. 1122-TR-2009-05-19 DATED SEPTEMBER 9, 2009.	DATE PREPARED: SEPTEMBER 2009 REVISION: 1 PREPARED BY: K. EKMAN/ S.HORSLEY PROJECT No: EG0926008.2200	**Photos 8 to 12** Taken: 2006

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TITLE: STUDY AREA		DWN BY: SR / TH	DATUM: NAD 83	DATE: SEPTEMBER, 2009
TASK: Preliminary Geotechnical Report on Proposed Coast Mountain Tunnels Route		APPRV'D BY: SK	REV. NO.: C	PROJECT NO: EG0926008-2200
		PROJECTION: UTM Zone 9	SCALE: 1:2 000 000	DRAWING NO. DRAWING 1

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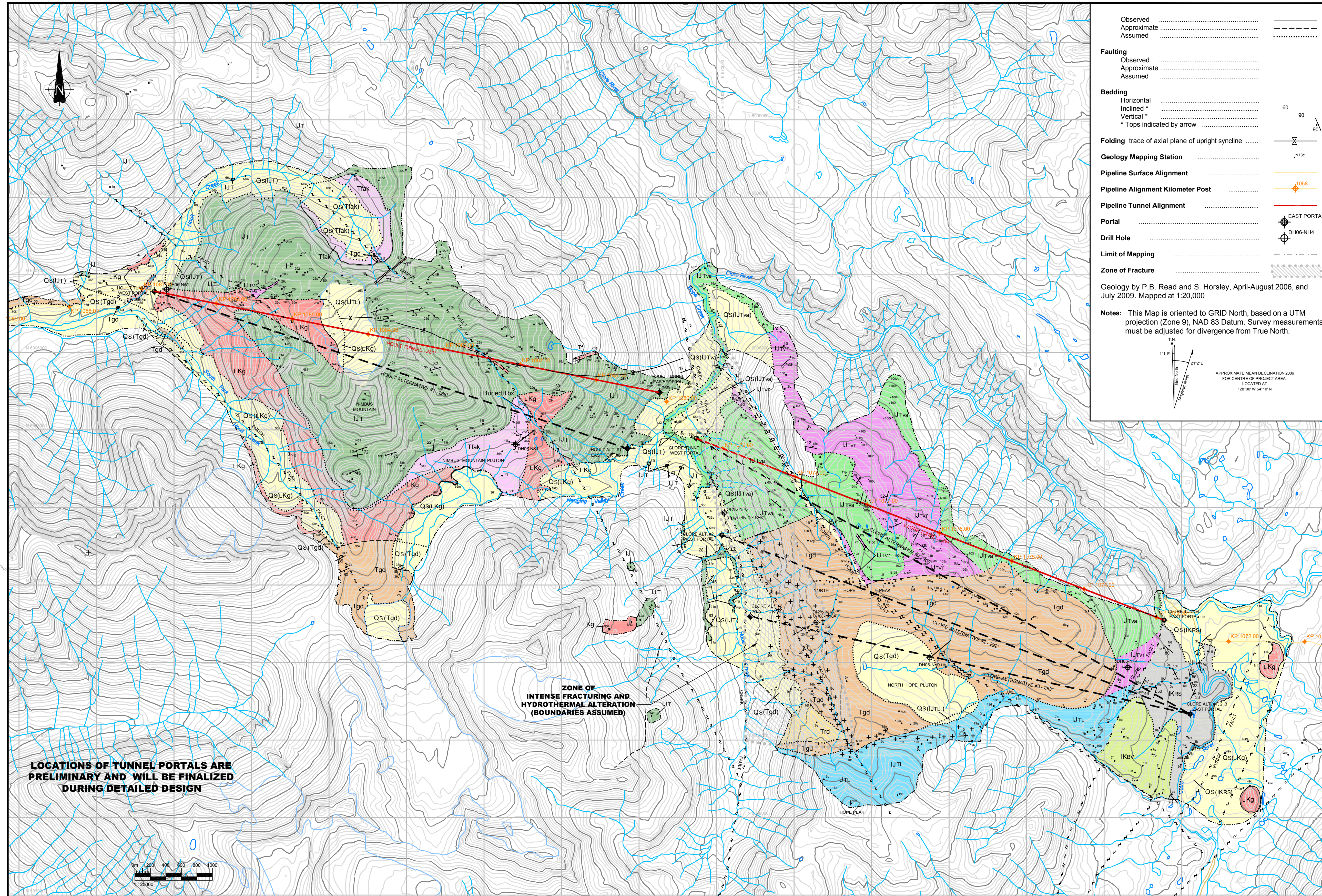

Pleistocene and Recent:

Qs	Alluvium and colluvium, few if any outcrops

TERTIARY

Eocene:

Trd	Post-tectonic porphyritic (biotite, plagioclase, quartz) rhyodacite dykes
Tf	Felsite dykes / Alaskite dykes
Tbx	Breccia of meta-tonalite, meta-andesite, and felsite clasts
Tfak	Undivided felsite, alaskite, granodiorite
Tgd	Post-tectonic granodiorite, quartz monzodiorite, monzodiorite, most have more biotite than hornblende, generally fresh unfoliated to weakly foliated

MESOZOIC (?) AND TERTIARY

Late Cretaceous (?) to Early Tertiary

LKd	*-Pre to post kinematic granodiorite, tonalite, granite; generally fresh; local ductile deformation, unfoliated to strongly foliated

MESOZOIC

Late Cretaceous (?)

Bulkley Intrusions(?)

LKtg	*Post-tectonic quartze diorite, diorite, granodiorite; most have more hornblende than biotite; fresh to highly altered; unfoliated to weakly foliated
LKg	Pre- to synkinematic granodiorite, tonalite; generally highly altered and cut by mafic dyke swarms; local to extensive ductile deformation

Lower Cretaceous:

SKEENA GROUP

Brian Boru Formation

lKBv	Grey-green andesite tuff, breccia, amygdaloidal flows

Red Rose Formation

lKRs	Dark grey shale, andesite to rhyolite tuff, minor greywacke

Jurassic (?) to Cretaceous (?)

JKd	*Greenschist facies diorite-tonalite complexes; lesser metavolcanic rocks; unfoliated to weekly foliated; intense brittle deformation

Upper Jurassic

BOWSER LAKE GROUP

Ashman Formation

muJA	*Siltstone, sandstone and conglomerate

Early and Middle Jurassic

Topley Intrusions(?)

Jg	*Pink granodiorite to granite; highly altered, unfoliated: intense brittle deformation

Lower and Middle Jurassic:

HAZELTON GROUP

Telkwa Formation

lJTu	*Upper Member: from base to top consists of conglomerate, sandstone, siltstone, red zeolitized lithic lapilli to ash tuff, quartz-bearing lithic tuff, partly welded feldspar crystal and lapilli dacite tuff, red zeolitized ash tuff, vitric ash tuff at top;
lJTva	Middle Member: varigated breccia, tuff and flows; conglomerate and volcanic sandstone common; andesite and feldspar porphyry widespread;
lJTvr	Rhyolite breccia and flows, locally layered; minor red tuff
lJTL	Lower Member: pyroxene±hornblende breccia, tuffs and flows
lJT	Undivided: basaltic to rhyolitic tuff, breccia and flows; minor sediments

PALEOZOIC

Lower Permian

lPs	*Limestone, calcareous mudstone; rare tuff and chert
lPc	*Fossiliferous limestone and silty limestone
lPs	*Grey-green siliceous flows, tuff and breccia; minor greywacke

AGE UNCERTAIN

lPs	*Amphibolite facies metamorphic rocks not assignable to other units
g	*Granitic rocks of uncertain age
+	Felsic to basic dykes

*Indicates rock units present regionally but not in map area.

FAULTING; CONTACT METAMORPHISM; REGIONAL METAMORPHISM; FAULTING; THRUSTING –FOLDING–; UNCONFORMITY; UNCONFORMITY; ANGULAR UNCONFORMITY –FOLDING–

NOTES:

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DATUM: NAD83
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DRAWN BY: PR, DSC, TH
APPROVED BY: PR, DSC
ORIGINAL SCALE: AS SHOWN

TASK: Preliminary Geotechnical Report on Proposed Coast Mountain Tunnels Route

TITLE: SITE PLAN showing TUNNEL ALIGNMENTS and SURFACE GEOLOGY

PROJECT NO.: EG0926008.2200
REVISION NO.:
DATE: SEPTEMBER, 2009
DRAWING NO.: Drawing 2
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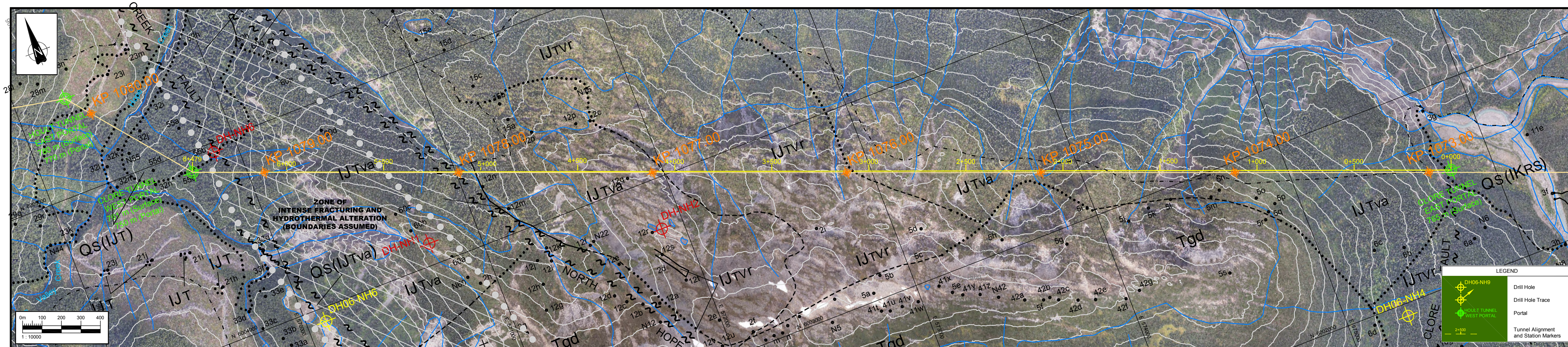

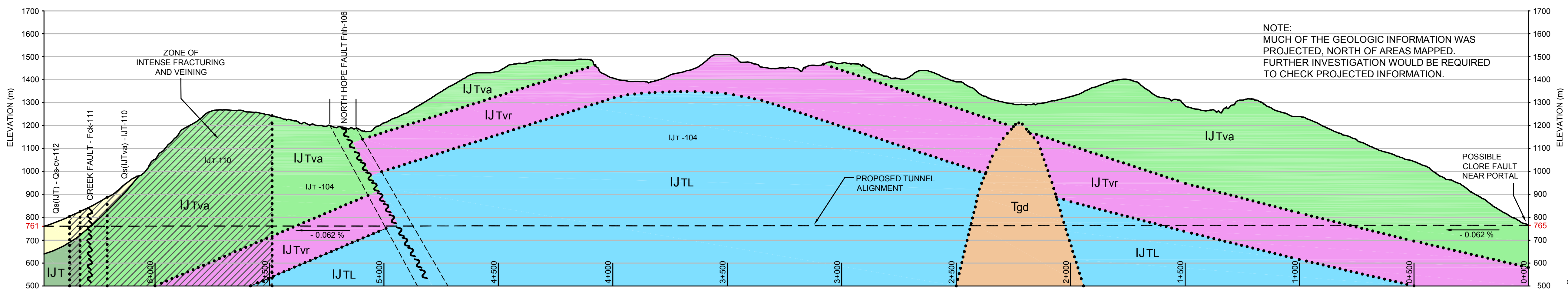

SECTION - CLORE TUNNEL

DOMAIN DESIGNATION	Qs-cv -112	Fck -111	IJT-110	IJT-104	Fnh-106	IJT-104
LITHOLOGY Geology by P.B. Read and S. Horsley, April - August 2006, and July 2009. (Mapped at 1:20,000)	Colluvium	Creek Fault Zone	Middle Member Telkwa Volcanics, meta-andesite flows in zone of intense fracturing	Middle Member Telkwa Volcanics, meta-rhyolite, meta-basalt, and/or meta-andesite flows.	North Hope Fault Zone	(PROJECTED) Lower Member Telkwa Volcanics, meta-basalt and meta-andesite flows, possible occurence Tertiary granodiorite pluton and Middle Member Telkwa rhyodacite flows
STRUCTURE	Soil	See Table 3.1	3 Joint Sets + Random. Fresh to Slightly Weathered. Ext. Close to Close Disc Spacing. Very Small Blocks, JRC 4-10 (est.)	3 Joint Sets + Random. Fresh to Slightly Weathered. Close to Wide Disc. Spacing. Med. Sized Blocks, JRC 6-12 (est.)	See Table 3.1	3 Joint Sets + Random. Fresh to Slightly Weathered. Close to Wide Discontinuity Spacing. Medium Sized Blocks, JRC 6-12 (est.)

DEPTH OF COVER (m): 301m, 493m, 457m, 681m, 651m, 753m, 714m, 631m, 565m, 526m, 476m, 278m, 0m

NOTES:
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2) FORMATION / GEOLOGY DESIGNATIONS AS PER LEGEND ON GEOLOGY PLAN.
3) DEPTH OF COVER SHOWN AS POINT DEPTHS AT 500m INTERVALS.
4) LOCATIONS OF TUNNEL PORTALS, PORTAL ELEVATIONS AND TUNNEL GRADES ARE PRELIMINARY AND WILL BE FINALIZED DURING DETAILED DESIGN.

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DATUM: NAD 83
PROJECTION: UTM Zone 9
DRAWN BY: TH
APPROVED BY:
ORIGINAL SCALE: AS SHOWN

TASK: Preliminary Geotechnical Report on Proposed Coast Mountain Tunnels Route

TITLE: CLORE TUNNEL PROFILE WITH TOPOGRAPHY AND GEOLOGY

PROJECT NO.: EG0926008.2200
REVISION NO.: C
DATE: SEPTEMBER, 2009
DRAWING NO.: Drawing 3
SHEET NO.:

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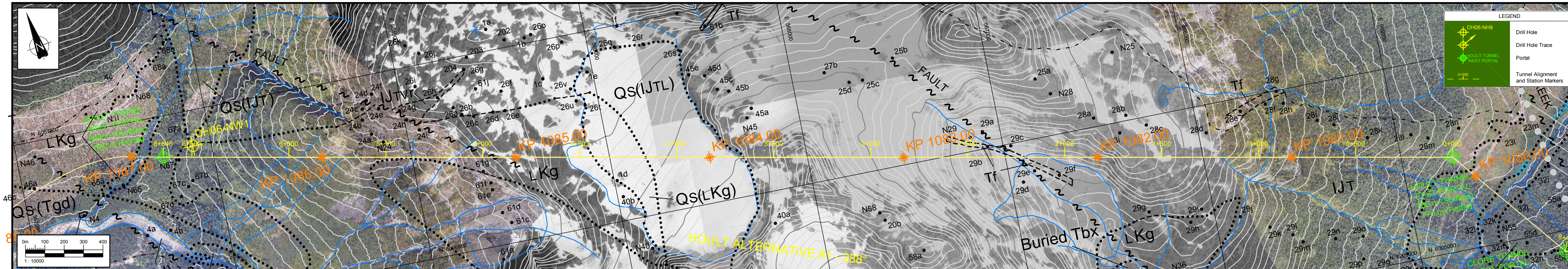

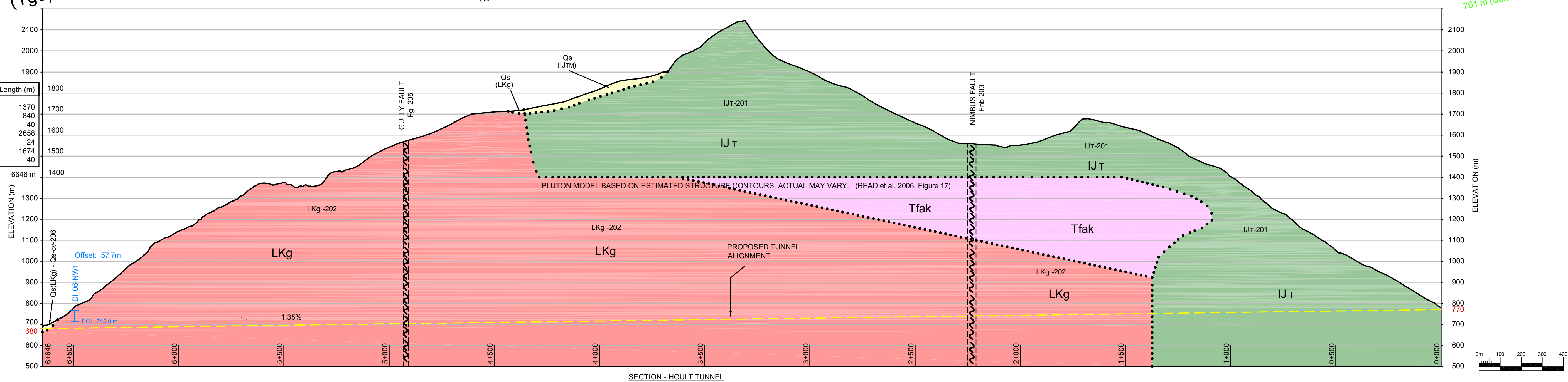

GEOLOGICAL STATIONS

Domain	From (m)	To (m)	Length (m)
IJT-201	0	1370	1370
LKg-202	1370	2210	840
Fnb-203	2210	2250	40
LKg-202	2250	4908	2658
Fgl-205	4908	4932	24
LKg-202	4932	6606	1674
Qs-cv-206	6606	6646	40

TOTAL LENGTH: 6646 m

DOMAIN DESIGNATIONS	Qs-cv-206	LKg - 202	Fgl - 205	LKg - 202	Fnb - 203	LKg - 202	IJT - 201
LITHOLOGY Geology by P.B. Read and S. Horsley, April - August, 2006 (Mapped at 1:20,000)	Colluvium	Meta-tonalite, meta-quartz diorite, and meta-alaskite.	Gully Fault Zone	Meta-tonalite, meta-quartz diorite, and meta-alaskite.	Nimbus Fault Zone	Meta-tonalite, meta-quartz diorite, and meta-alaskite.	Meta-andesite lithic tuff, some phyllitic partings.
STRUCTURE	Soil	3 Joint Sets + Random, JRC 8-14. Fresh to Slightly Weathered. Close to Very Wide Discontinuity Spacing. Medium to Small Blocks.	See Table 3.2	3 Joint Sets + Random, JRC 8-14. Fresh to Slightly Weathered. Close to Very Wide Discontinuity Spacing. Medium to Small Blocks.	See Table 3.2	3 Joint Sets + Random, JRC 8-14. Fresh to Slightly Weathered. Close to Very Wide Discontinuity Spacing. Medium to Small Blocks.	

DEPTH OF COVER (m): 94m | 453m | 677m | 839m | 1000m | 1102m | 1318m | 1170m | 921m | 809m | 887m | 646m | 288m | 10m

NOTES:
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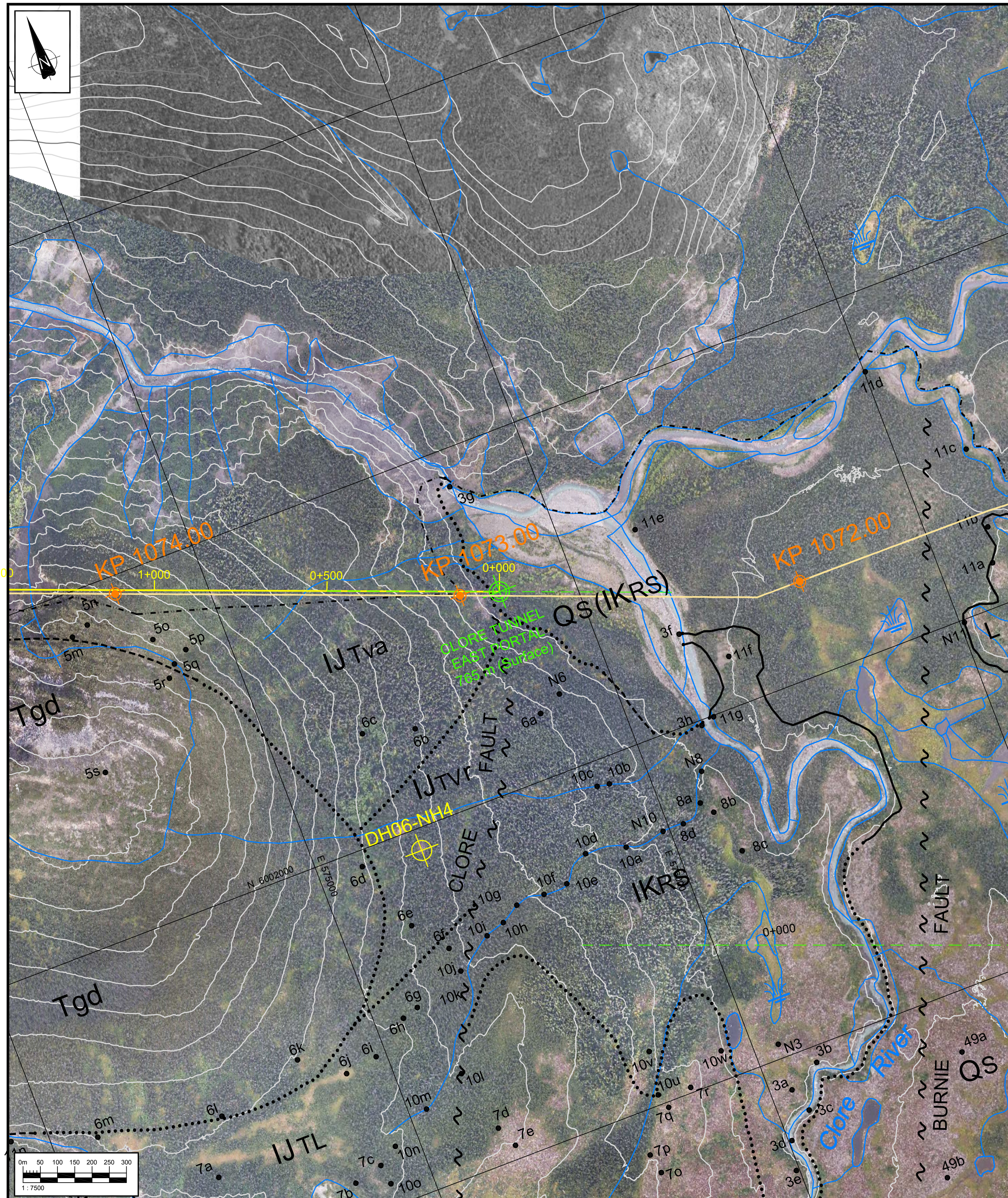
PROJECTION: UTM Zone 9
DRAWN BY: TH
APPROVED BY:
ORIGINAL SCALE: AS SHOWN

TASK: Preliminary Geotechnical Report on Proposed Coast Mountain Tunnels Route

TITLE: HOULT TUNNEL
PROFILE WITH TOPOGRAPHY AND GEOLOGY

PROJECT NO.: EG0926008.2200
REVISION NO.: C
DATE: SEPTEMBER, 2009
DRAWING NO.: Drawing 4
SHEET NO.:



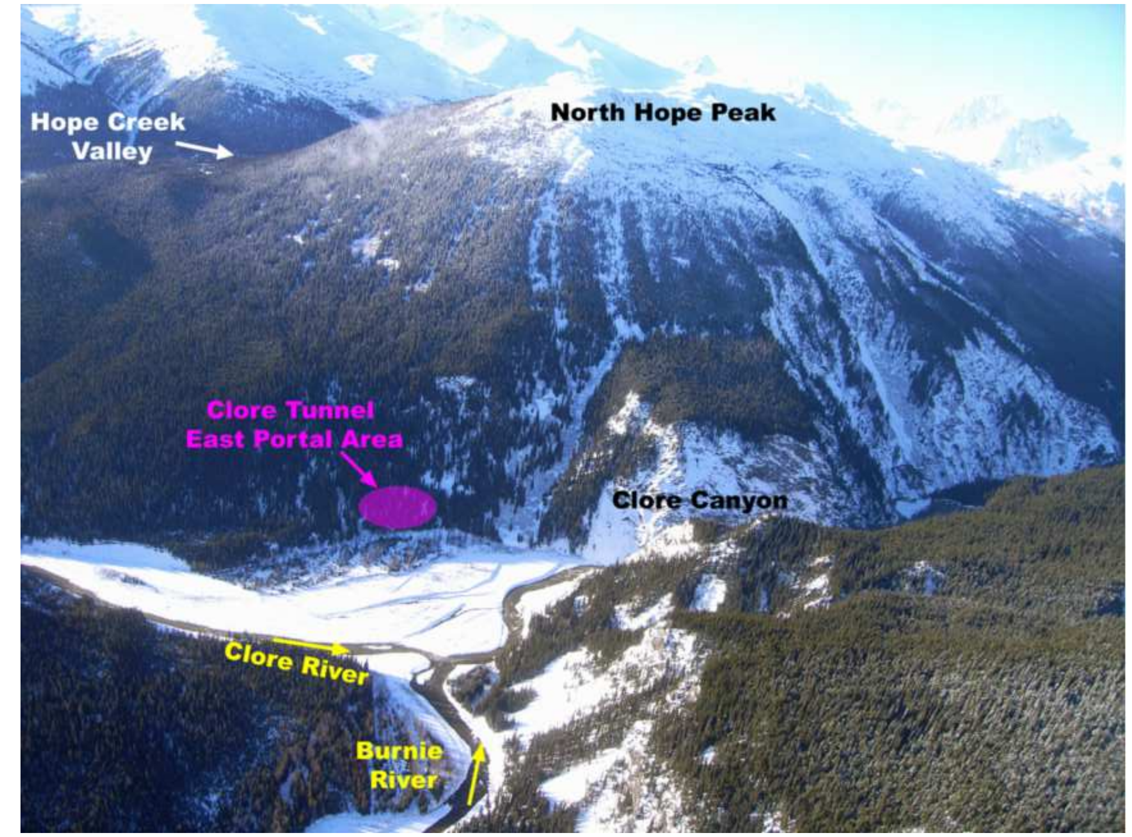
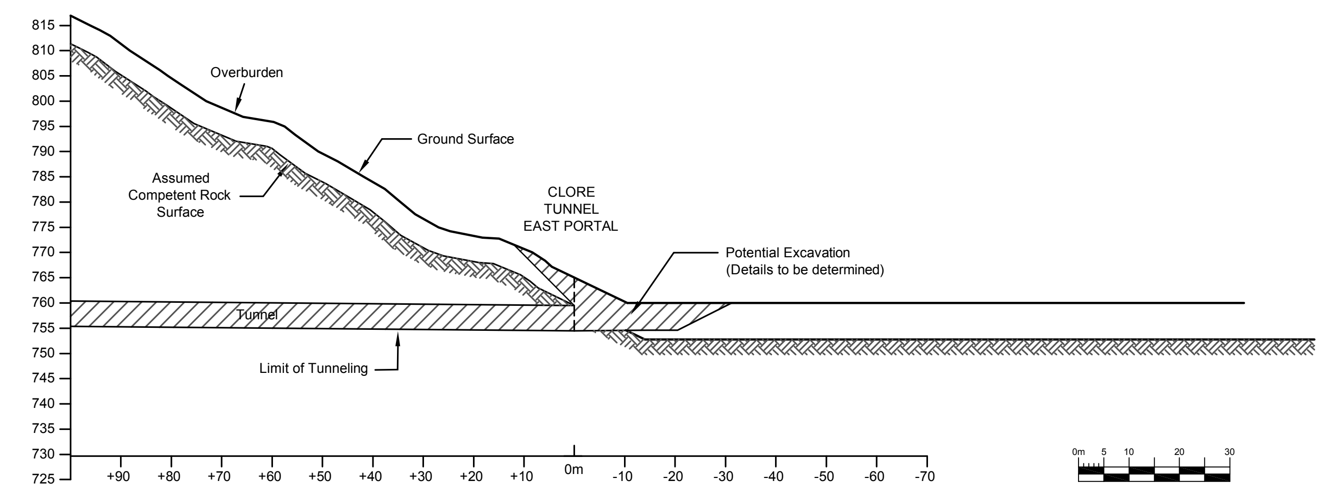


PHOTO 1: LOOKING WEST



DETAIL: CLORE TUNNEL EAST PORTAL SECTION

COMMENTS / NOTES:

1. CROSS SECTION SHOWN BASED ON CLORE TUNNEL ALIGNMENT.
2. OVERBURDEN THICKNESSES ARE ESTIMATES ONLY.
3. LOCATIONS OF FACILITIES ON PHOTOS ARE APPROXIMATE.
4. LOCATIONS OF TUNNEL PORTALS, PORTAL ELEVATIONS AND TUNNEL GRADES ARE PRELIMINARY AND WILL BE FINALIZED DURING DETAILED DESIGN.
5. FOR DISCUSSION PURPOSES ONLY.

NOTE:
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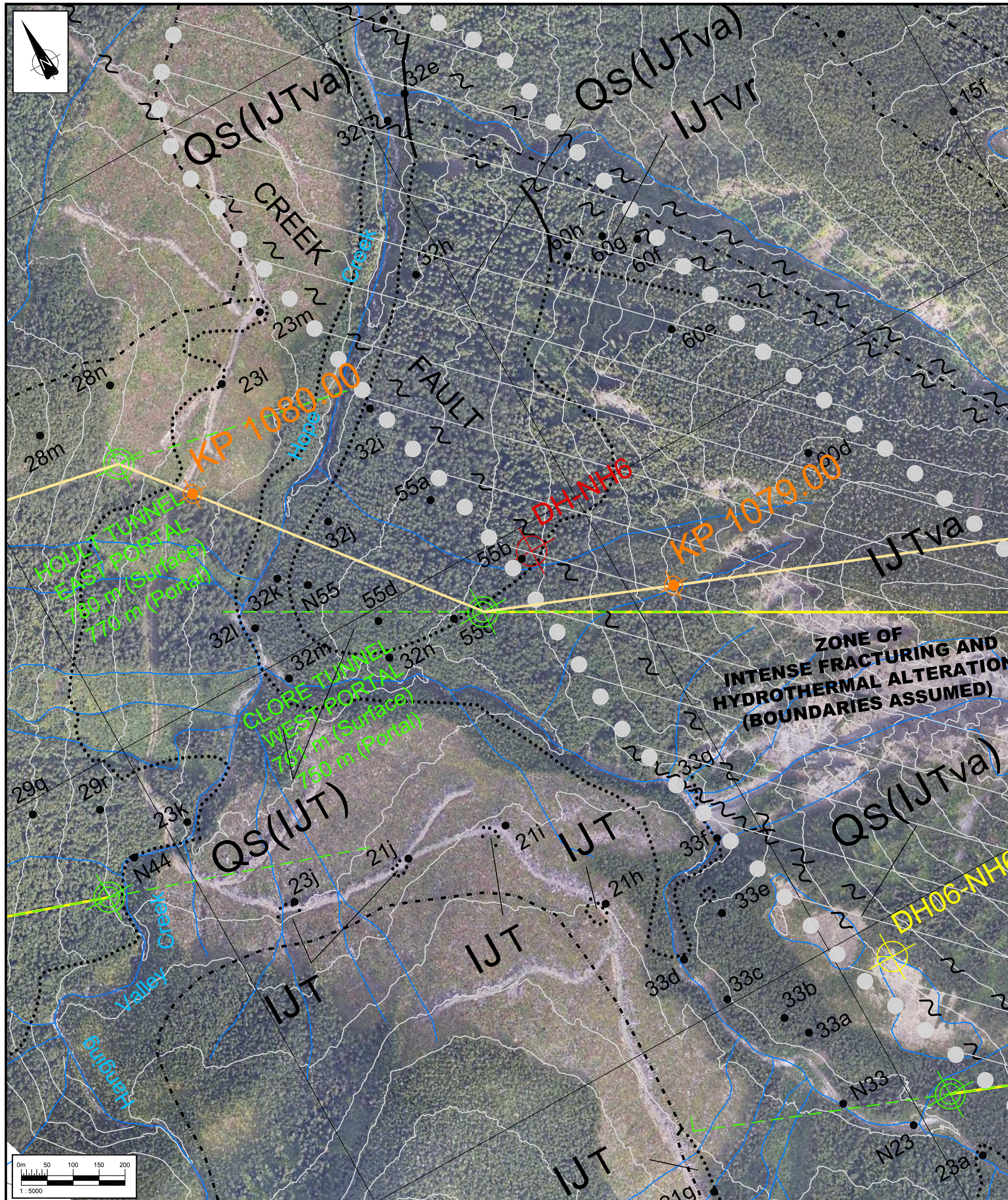
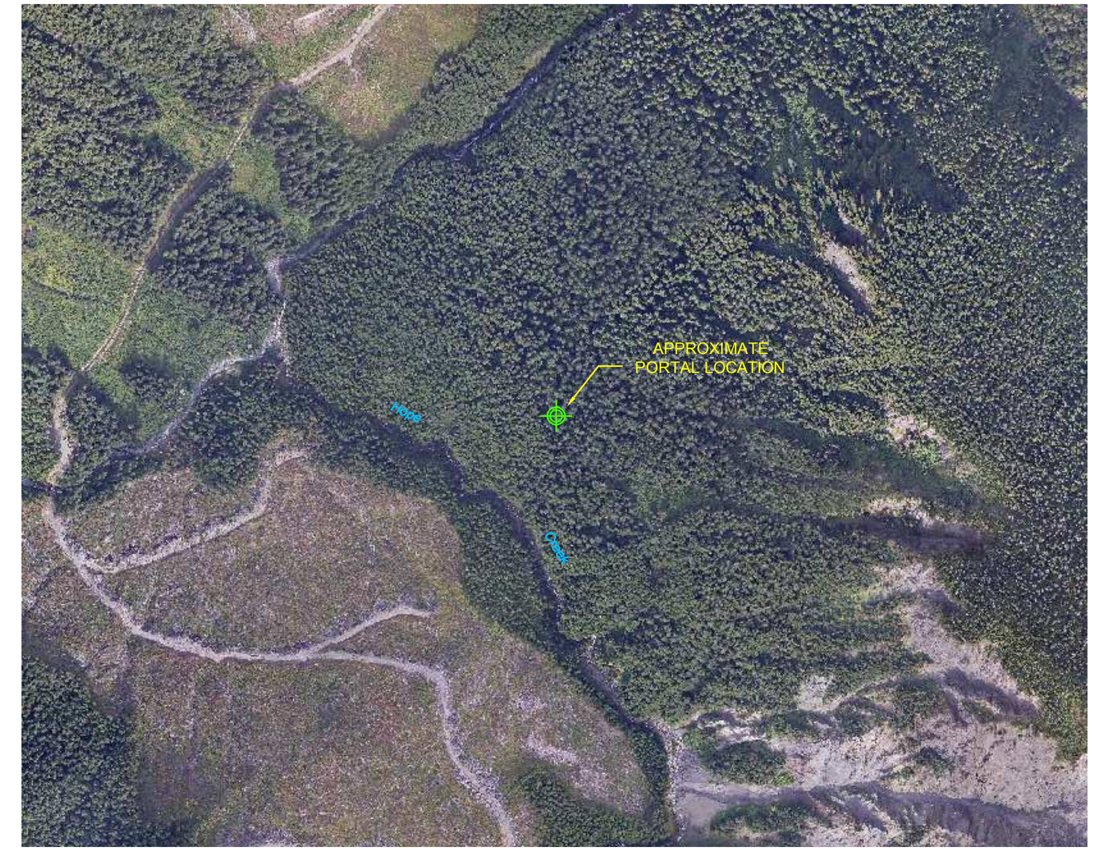
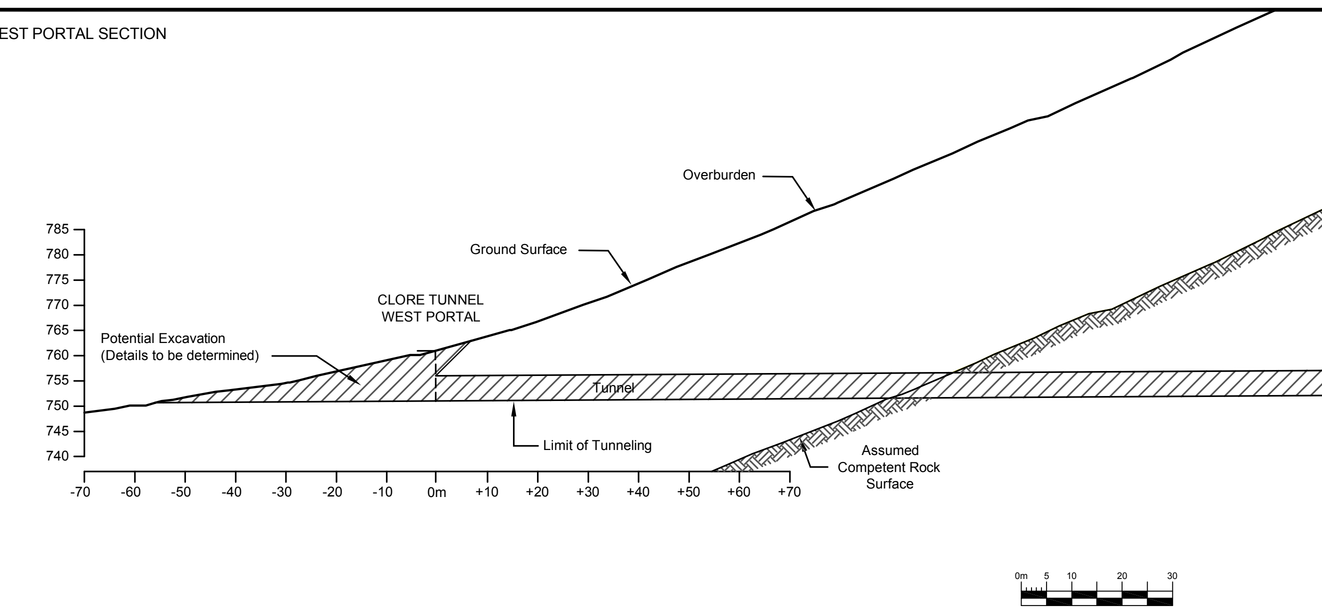




DETAIL: CLORE TUNNEL - WEST PORTAL SECTION



COMMENTS / NOTES:

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TASK: Preliminary Geotechnical Report on Proposed Coast Mountain Tunnels Route

TITLE: CLORE TUNNEL WEST PORTAL DETAIL

PROJECT NO.: EG0926008.2200
REVISION NO.:
DATE: SEPTEMBER, 2009
DRAWING NO.: Drawing 6
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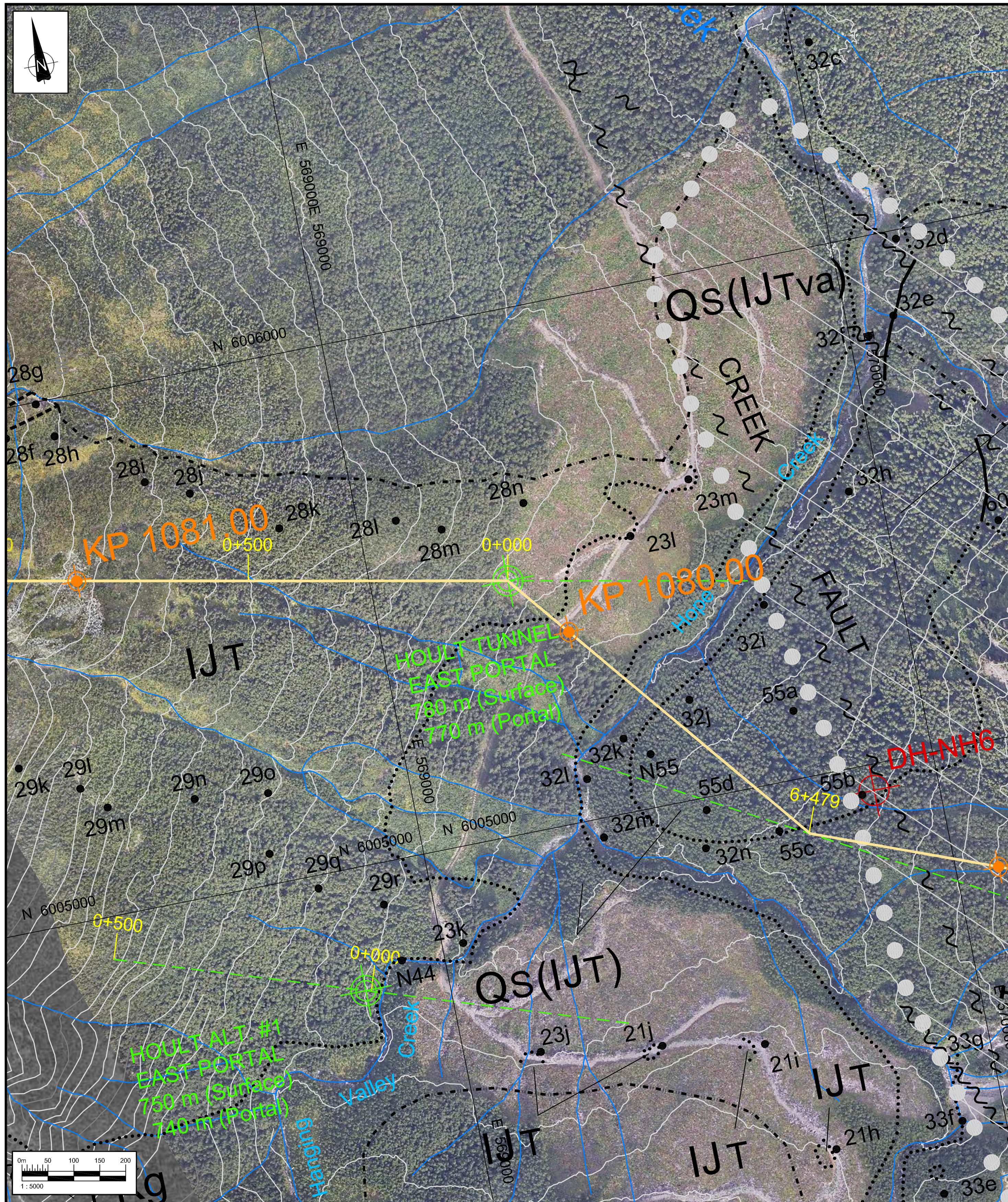


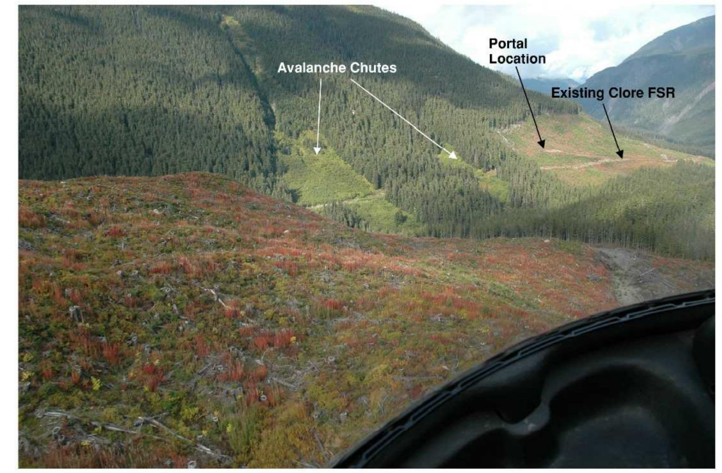


Photo 29: Looking northwest.

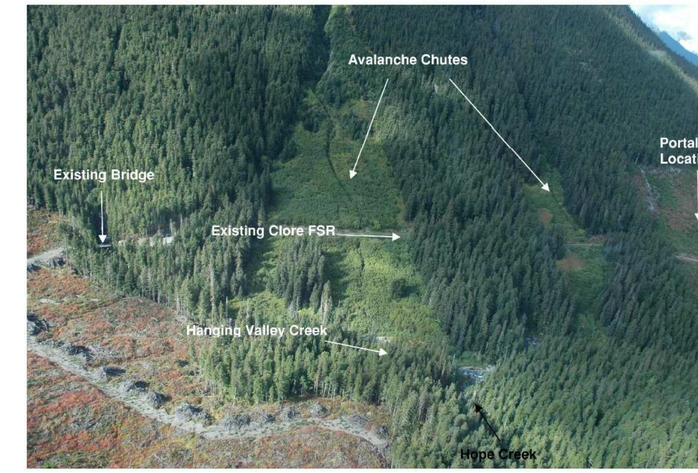
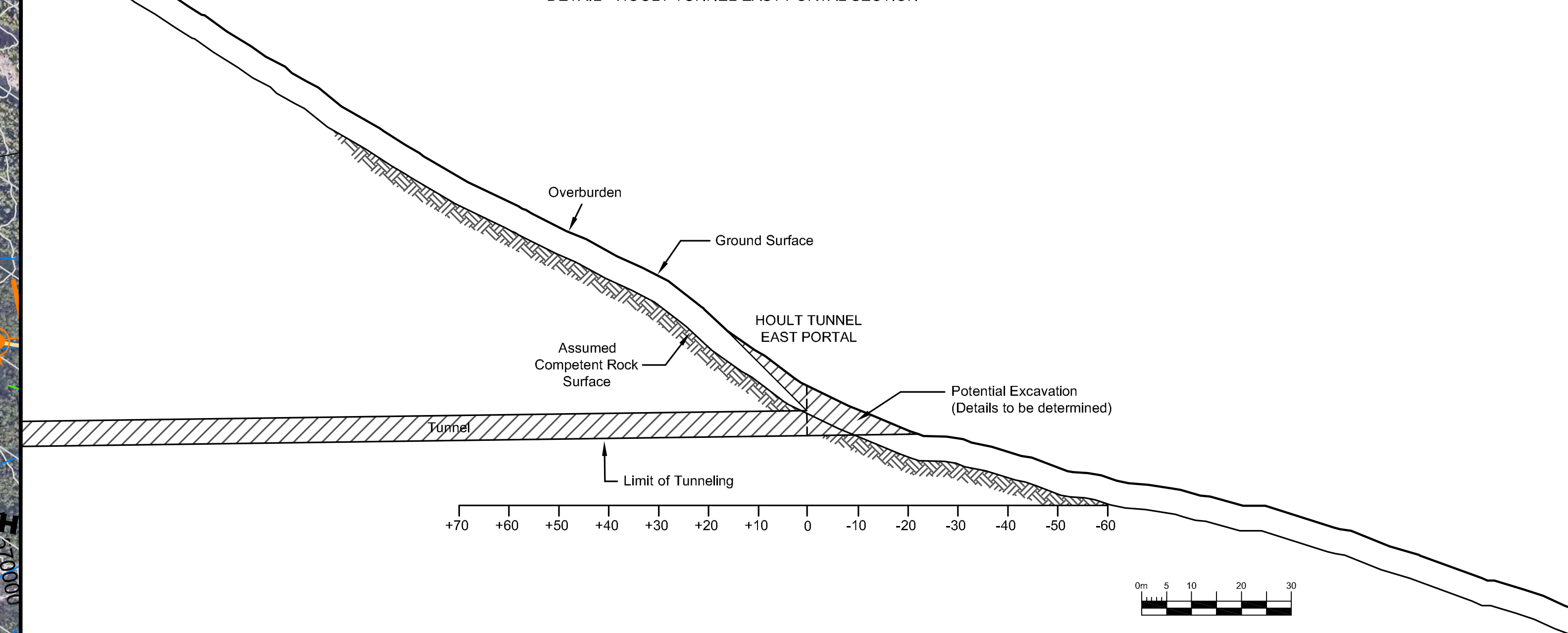


Photo 30: Looking west.

DETAIL - HOULT TUNNEL EAST PORTAL SECTION



COMMENTS / NOTES:

1. CROSS SECTION SHOWN BASED ON HOULT TUNNEL ALIGNMENT.
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ORIGINAL SCALE: AS SHOWN

TASK: Preliminary Geotechnical Report on Proposed Coast Mountain Tunnels Route

TITLE: HOULT TUNNEL EAST PORTAL DETAIL

PROJECT NO.: EG0926008.2200
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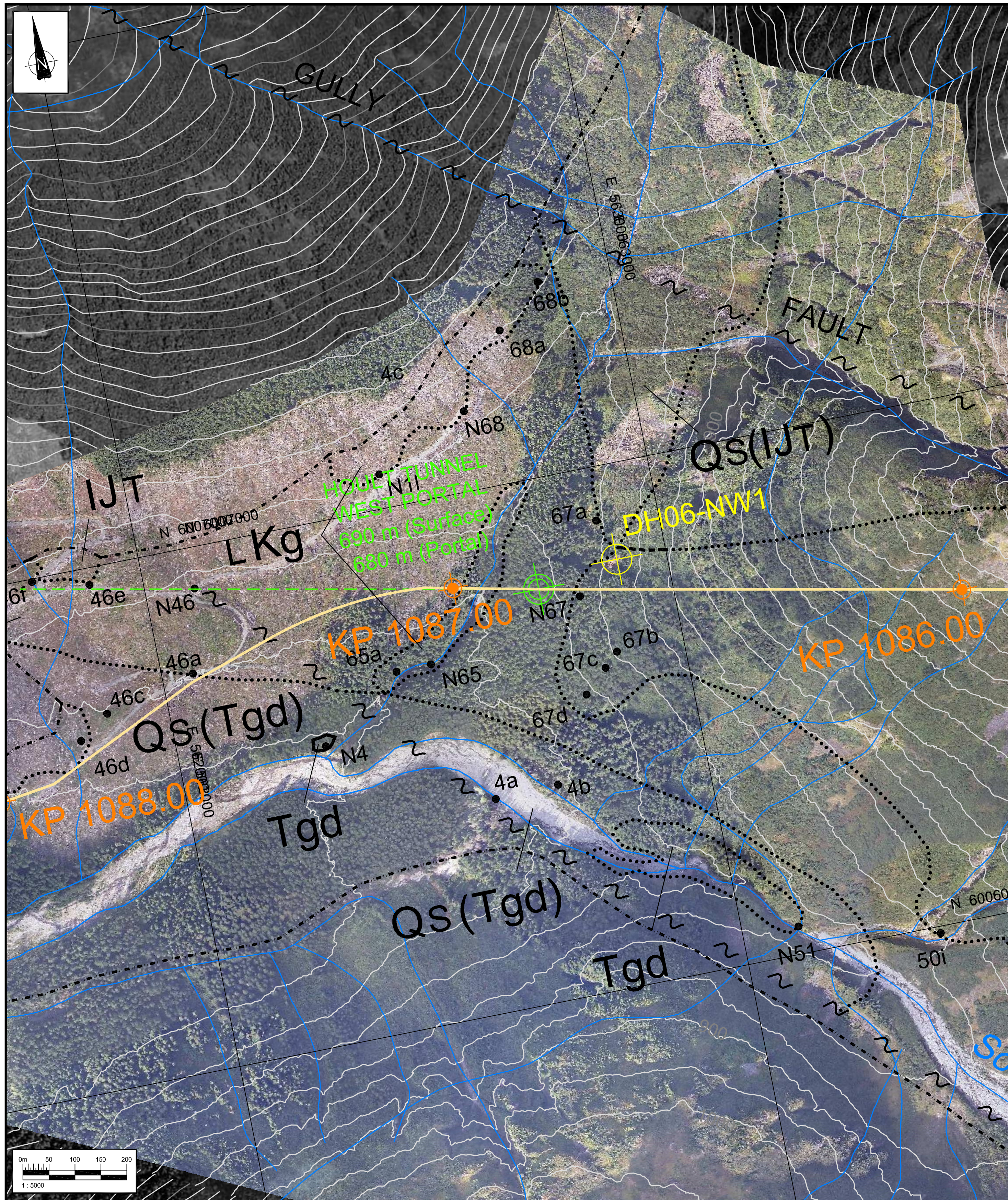
SHEET NO.:



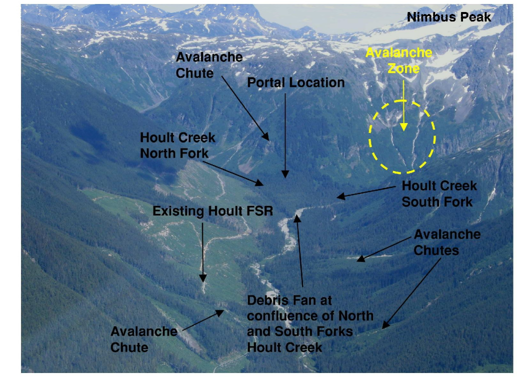


Photo 31: Looking northeast.

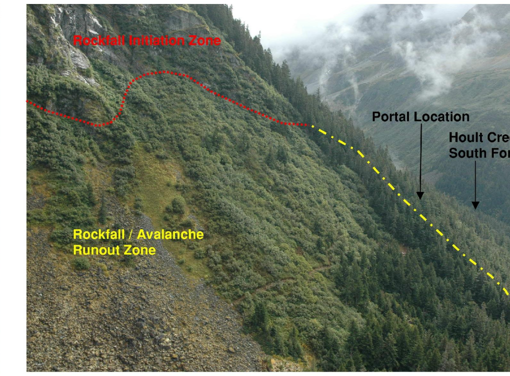


Photo 32: Looking southeast.

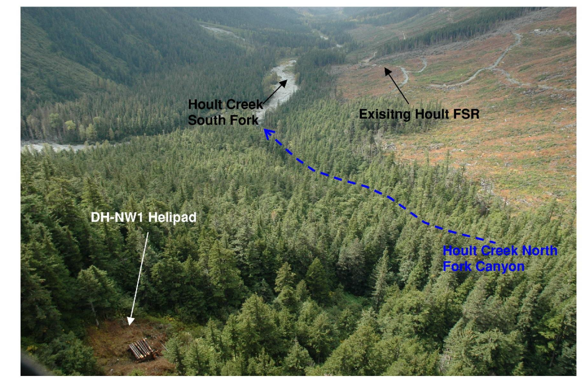


Photo 33: Looking southwest.

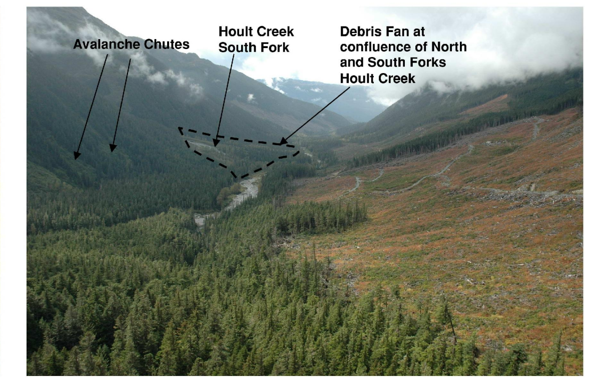
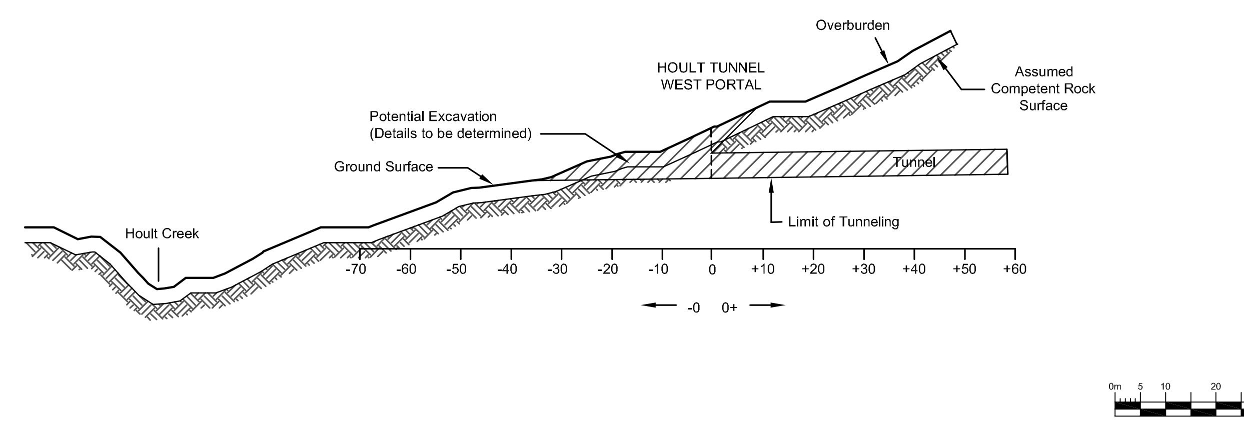


Photo 34: Looking southwest.

DETAIL - HOULT TUNNEL WEST PORTAL



COMMENTS / NOTES:

1. CROSS SECTION SHOWN BASED ON HOULT TUNNEL ALIGNMENT.
2. OVERBURDEN THICKNESSES ARE ESTIMATES ONLY.
3. LOCATIONS OF FACILITIES ON PHOTOS ARE APPROXIMATE.
4. LOCATIONS OF TUNNEL PORTALS, PORTAL ELEVATIONS AND TUNNEL GRADES ARE PRELIMINARY AND WILL BE FINALIZED DURING DETAILED DESIGN.
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ENBRIDGE NORTHERN GATEWAY PIPELINES

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DRAWN BY: TH
APPROVED BY:
ORIGINAL SCALE: AS SHOWN

TASK: Preliminary Geotechnical Report on Proposed Coast Mountain Tunnels Route

TITLE: HOULT TUNNEL WEST PORTAL DETAIL

PROJECT NO.: EG0926008.2200
REVISION NO.: C
DATE: SEPTEMBER, 2009
DRAWING NO.: Drawing 8
SHEET NO.: 1 of 1

APPENDIX A

Structural Domain Details and ISRM Classifications

APPENDIX A – DETAILED DESCRIPTIONS OF GEOLOGICAL DOMAINS

A.1 North Hope Peak Domains

A.1.1 Red Rose Sedimentary Rocks (lKRS-101 and 102)

- The Red Rose Formation is divided into 2 structural domains as follows:
  - **(lKRS -101),** near surface zone at the common east portal of the Clore Alternative 1, 2 and 3 options.
  - **(lKRS -102)**, the main Red Rose Formation rocks that occur on the east side of North Hope Peak.
- The Red Rose Formation is located on the lower eastern flank of North Hope Peak, east of the Telkwa Formation volcanics. The contact between the Red Rose Formation and the adjacent Telkwa Formation is thought to be a fault (Clore Fault); however, the fault has not been observed in the field or in drilling to date. Note that the orientation of the fault is assumed, as surface outcrops of the fault were not observed.
- The formation consists of sedimentary and volcanic rocks that have been subjected to low grade metamorphism. The rock types include massive to poorly bedded, folded, Lower Cretaceous siltstone, variably pyritiferous argillite (low grade fine-grained metamorphic rock broadly similar to slate but without well-developed cleavage), and tuff (volcanic rock). Sandstone also occurs in the Red Rose Formation. The formation is poorly exposed except along the Clore River where a canyon has been cut into the moderately weak to moderately strong rock mass.
- The basic dykes generally present in the rocks of the North Hope Peak Region were not observed in the Red Rose Formation.
- The Red Rose Formation is reported to contain sulphide mineralization; however, initial tests suggest that in addition to the presence of sulphides, the rock contains an appreciable level of carbonate that acts to reduce the potential that oxidation of the sulphides would lead to Acid Rock Drainage/Metal Leaching (ARD/ML). The overall potential for the generation of ARD from this unit appears to be low. The results of ARD/ML testing are reported under separate cover.
- Due to poor surface exposures along the tunnel options, only sparse joint data is available. For the purposes of this report, the joints have been assumed to be similar in orientation to the adjacent Telkwa Formation; however, continuity may be much less due to the folded sedimentary rocks. Due to the lack of data, only assumed orientations are provided.
- The Red Rose rocks are considered to be suitable for tunnelling, but may have zones of relatively low strength and unfavourable structure, and additional considerations for ARD/ML potential of excavated rock make this a unit requiring further engineering evaluation.

A.1.2 Brian Boru Volcanic Rocks (No Domain)

- The Brian Boru Formation will not be encountered along the proposed tunnel alignments at tunnel elevation. The formation is interpreted to be present above the proposed Clore Alternative 3 tunnel alignment.
- The Brian Boru Formation occurs on the eastern side of North Hope Peak, and is in conformable contact with the underlying Red Rose Formation. Along the west side, the formation is in faulted contact with the Telkwa Formation (Domain lJTM-104) along the Clore Fault discussed above.
- The Brian Boru Formation is poorly exposed and consists of meta-andesite tuff or volcanic breccia and amygdaloidal volcanic flows.
- Rock strength and joint patterns are not provided as it is not anticipated that this rock unit will be intersected along the proposed tunnel alignments.

A.1.3 Clore Fault (Fcl-103)

- The Clore Fault is located on the east end of the project area, and defines the unconformity between the combined group of Brian Boru Volcanics and Red Rose Sedimentary Rocks (**lKRS**-102) to the east and the Telkwa Volcanics (lJTM-104) to the west. Exposures of the fault have not been identified across the project area and its position has been assumed based on nearby outcrops.
- The fault is oriented north-northeast and is assumed to be steeply dipping (sub-vertical), based on the structural relationships between surface outcrops and the core recovered from DH06-NH4.
- The fault has an estimated true thickness of 40 m, based on surface expression and spacing of available surface outcrops.
- Based on the assumed strike, the fault intersects the tunnel axes at relative angles of about 80° and 90° from the tunnel heading, resulting in a total intersection length along a hypothetical 5 m circular tunnel of around 70 m.

A.1.4 Telkwa Volcanics (lJTM-104)

- This domain comprises the majority of the Lower to Middle Jurassic Telkwa Formation volcanic rocks identified in the North Hope Peak Region, with the exception of a zone along the northwest flank of the region that is highly fractured (see Domain lJTM-110 below).
- The rock is relatively intact and is comprised of volcanic rocks (variegated breccia, tuff and flows, frequent conglomerate and volcanic sandstone and feldspar porphyry). Typically, the overall rock is made up of meta-basalt and meta-andesite flows.
- The Domain lJTM-104 Telkwa Volcanic rocks in the North Hope Peak area contain andesite and basalt dykes that are typically 0.5 m to 10 m thick, with strikes between 310° and 312° and typical dips of between 80° and 90° to the NE. The contacts of the dykes with the host rock are generally frozen (i.e., not an open joint). The dykes appear to pre-date the last significant fault movements and are also younger than the plutonic rocks as evidenced by their

displacements and the persistence of the dykes across regional geological contacts.

- The potential for the Telkwa Formation to contain appreciable sulphide bearing zones that might result in ARD/ML issues is low; however, as reported under separate cover, the ARD/ML work indicated a few very local areas that might correspond to local potential acid generating conditions.
- The Telkwa Volcanics are considered a favourable rock unit for advancement of tunnelling using TBM or drill and blast methods. The rock is relatively fine grained and has a high UCS.

A.1.5 North Hope Pluton (Tgd-105)

- This domain comprises the majority of the Tertiary Plutonic rocks identified at surface in the North Hope Peak (Clore Tunnel) Region, with the exception of a highly fractured zone along the northwest flank of the region that is defined as a separate domain.
- The intact rock is a Tertiary age, uniform, medium-grained (1 to 3 mm), quartz-rich, plutonic, igneous intrusive rock, typically defined as granodiorite. Detailed thin section petrography indicated that it is a biotite horneblende granodiorite with weak chlorite-sericite alteration, generally containing about 20-25% quartz.
- As with most of the rock domains along the Clore Tunnel options, the Tertiary plutonic rocks in the North Hope Peak area contain andesite and basalt dykes ranging from about 0.5 m to 10 m thick, with strikes around 310° to 312° and average dips of 80° to 90° to the NE. The dykes are typically frozen to the host rock (not open joint at contact), appear to pre-date the last significant fault movements, and appear to post-date the placement of the plutonic rocks.
- The mineralogical potential for this unit to contain appreciable sulphide bearing zones that would indicate a potential for ARD/ML issues is very low.
- The granodiorite of the North Hope Pluton is considered as a favourable rock unit for advancement of tunnelling using TBM or drill and blast methods. The unit is relatively massive and contains appreciable amounts of quartz which could slow advance rates and increase abrasion using TBM methods. The massive nature and relatively high strength of the rock will likely result in low support requirements.

A.1.6 North Hope Fault (Fnh-106)

- The northwest trending North Hope Fault cuts through all the geological units in the North Hope Peak area. Surface geological mapping suggests that the fault pre-dates the placement of the North Hope Peak Plutonic rocks; however, re-activated movement along the fault has resulted in displacements through the plutonic rocks as well. Relative displacements in the younger plutonic rocks are much less than displacements through the adjacent, much older Telkwa Volcanic rocks.
- The fault trace is sub-vertical and runs in a northwesterly trend across North Hope Peak.

- The apparently larger fault movements prior to placement of the plutonic rocks and small movements after the placement of the plutonic rocks have resulted in variable fault zone widths depending on the age of and amount of movement within the particular rock type involved.
- Where the Tgd-105 domain is located on both sides of the fault, only limited fracturing appears to be present with very little actual movement along the fault trace. The true width of the fault zone is estimated to be about 15 m. This portion of the fault intersects the proposed Clore Alternative 3 at a relative angle of between about 30° and 35° from the tunnel heading, resulting in a total intersection length along a hypothetical 5 m circular tunnel of between 34 and 40 m.
- Where the North Hope Fault is bordered by younger plutonic rocks on one side and older volcanic rocks on the other (between Clore Alternative 1 and 2 alignments) and through only older volcanic rocks only (Clore Alternative 1 alignment), the damage zone is thought to be much wider as a result of much larger movements across the fault. The fault zone is estimated at 75 m wide (true thickness) in this portion of the fault trace. Where it intersects the Clore Alternative 1 tunnel axis at a relative angle of 30° from the tunnel heading this results in a total intersection length along a hypothetical 5 m circular tunnel of about 160 m.

A.1.7 Closely Fractured North Hope Pluton (Tgd-107)

- This rock mass comprises a highly fractured and veined zone of Tertiary plutonic rocks. The highly fractured and veined zone includes both the plutonic rocks in this zone as well as Telkwa Formation rocks to the northwest (Domain lTJM-104). The fractured zone trends northeast-southwest along the northwest flank of North Hope Peak, roughly parallel to the Hope and Creek Faults.
- The domain contains highly fractured plutonic rocks corresponding to Domain Tgd-105 with numerous veins of calcite, chlorite, zeolites, epidote and tremolite-actinolite. The mineralogy of the veins indicates at least two episodes of placement under different geological conditions and several of the mineral types are generally associated with relatively weak rock conditions.
- The mineralogy becomes increasingly altered with depth. At 365 m depth in drill hole DH06-NH8, a significantly altered monzodiorite (plutonic rock) was encountered. The dykes and ARD/ML potential are thought to be similar to the Tertiary plutonic rock described above (Domain Tgd-105).
- The unconfined compressive strength (UCS) of intact rock appears to be lower than that of the mineralogically similar Domain Tgd-105; however, this is only based on observation as few intact rock specimens collected were of suitable size to conduct UCS tests due to the intense fracturing. For the purposes of this report, the intact rock strength is estimated based on observation and point load testing and is for small fragments of rock since as noted above, the rock was intensely fractured with frequent veins and low RQD values. The estimated strength may be on the high side and may be biased by the recovered rock samples that were suitable for the limited point load testing done.

- The joint sets are projected to be similar to the regional joint sets discussed above in Domain Tgd-105; however, there is less information on continuity since access to exposures of this domain was very difficult and only a few joints were observed. It should also be noted that there was no emphasis on observations in this particular area during the field mapping since recognition of the area as a separate domain was the result of later core logging. The joint summary data for Domain Tgd-105 is repeated for this domain with the caution that continuity, in particular, may vary in the highly fractured and veined rock mass.
- The broken nature of the Closely Fractured North Hope Plutonic rocks will likely increase permeability and water storage in the rock mass, increase support requirements, and result in significantly slower average advance rates for drill and blast tunnelling methods and possibly TBM methods, as compared to the parent Tgd-105 rocks. Additional engineering investigation and analysis is recommended to examine potential water concerns and general support requirements, particularly near known fault zones.

A.1.8 Hydrothermally Altered Closely Fractured North Hope Pluton (Tqmd-108)

- This rock mass comprises a hydrothermally altered, highly fractured and veined zone of Tertiary plutonic rocks. The fractured zone trends northeast-southwest along the northwest flank of North Hope Peak, roughly parallel to the Hope and Creek Faults, below an elevation of about 1100 m. The elevation is known only in detail from one hole intersection and the top is likely not horizontal (see sections); however, it is clear that the altered rock extends well above the proposed tunnel elevations (see sections).
- The domain contains hydrothermally altered, highly fractured biotite quartz monzodiorite with a typical quartz content of about 10-12%. Much of the original mineralization has been altered to chlorite resulting in a much weaker rock mass. Cataclastic deformation has caused intense fracturing and lead to granulation and recrystallization in seams and patches throughout the rock mass.
- Thin sections show that the original biotite, horneblende and pyroxene have been altered to chlorite and calcic plagioclase now altered to albite.
- The dykes and ARD potential are thought to be similar to the Tertiary plutonic rock described above (Domain Tgd-105).
- The estimates of unconfined compressive strength (UCS) of intact rock and orientations of joint sets for this domain are assumed to be less than those for Domain Tgd-107, which as noted above were based on estimates and similarities to Domain Tgd-105; therefore, caution is given that UCS values may be on the high side and joint sets may vary in the highly fractured and veined rock mass.
- The behaviour of this unit in response to tunnelling is expected to be similar to worse compared to the previously described rock mass. In particular, some of the rock core was sufficiently weak that it could be broken between the fingers of one hand. It is likely that the weakest rock broke during drilling and was not recovered in a state permitting strength tests to be carried out. Further assessment of the extent of hydrothermal alteration is recommended.

A.1.9 Closely Fractured Telkwa Volcanics (lJTM-110)

- This domain comprises a northeast-southwest trending zone of Telkwa Formation volcanic rocks located along the northwest flank of the region, roughly parallel to Hope and Creek Faults and present at the west ends of some of the Clore Tunnel options. This domain is northwest of Domain Tgd-107 and, like that domain, the parent rock (Telkwa Formation in this case) has been subjected to severe fracturing and veining. Surface exposures are poor and those that exist are on steep terrain with rock fall hazards and are difficult to access.
- The parent rock apparently has similar mineralogy, dykes, and ARD/ML potential to the Telkwa Formation volcanics described above (Domain lJTM-104).
- The rock is closely fractured and veined. Due to a lack of drill holes, there is less information available than for Domain Tgd-107; however, broadly similar conditions are projected.
- The unconfined compressive strength (UCS) of intact rock is believed to be lower than that of the mineralogically similar unit in Domain lJTM-104; however, this is based on very limited observation of surface exposures and no drill hole information. For the purposes of this report, the intact rock strength was assumed, and this assumption may be on the high side.
- The behaviour of this unit is expected to approach that of the above-mentioned closely fractured rock masses, although these rocks are older, which suggests that the fracturing may be more intense, and poorer ground conditions could be expected as a result.

A.1.10 Hope Fault (Fh-109)

- Hope Fault is a northwest trending, sub-vertical fault located on the western side of North Hope Peak. The fault intersects the west ends of the Clore Alternative 2 and 3 alignments, and terminates at the Creek Fault (see below) south of the Clore Alternative 1 alignment.
- The fault is believed to pre-date the North Hope plutonic intrusion (similar to North Hope Fault), but unlike the small movements seen in North Hope Fault to the east, the movement along the Hope Fault within the younger plutonic rocks appears to have resulted in up to 100 m displacement.
- The relatively large movements have resulted in a wide damage zone surrounding the fault trace, estimated to be up to 100 m wide (true thickness).
- The fault trace intersects the Clore Alternative 2 and 3 tunnel axes at relative angles of between 40° and 45° from the tunnel heading, resulting in total intersection lengths along a hypothetical 5 m circular tunnel of between about 145 m and 160 m.

A.1.11 Creek Fault (Fck-111)

- Creek Fault is a north trending, sub-vertical fault located on the western side of North Hope Peak, roughly parallel to Hope Creek. The fault trace is near to the western ends of Clore Tunnel and Clore Alternatives 1, 2 and 3.

- The fault is believed to pre-date the North Hope Peak plutonic intrusion (similar to other regional faults), and likely represents the most significant structural movement in the area. Evidence of significant movement includes the abrupt termination of the west end of the North Hope Pluton rocks.
- The relatively large movements have resulted in a wide damage zone surrounding the fault trace, estimated to be up to 100 m wide (true thickness).
- The fault trace intersects the Clore Alternative 1 and 2 tunnel axes at relative angles of between 50° and 55° from the tunnel heading, resulting in total intersection lengths along a hypothetical 5 m circular tunnel of between about 125 m and 135 m.

A.1.12 Colluvium & Soft Ground Conditions at Western portals (Qs-cv-112)

- Significant colluvium deposits are believed to exist at the western portals of the Clore Tunnel options.
- DH06-NH6, drilled near the western portal of the Clore Alternative 2 option did not encounter bedrock to a vertical depth of 40 m.
- Additional information is required to define the depths of materials (and consequently the length of this structural domain at the tunnel portals), but for the purposes of design, the thickness has been assumed to be 40 m perpendicular to the existing slope profile. It is thought that this estimate may be low, particularly for the Clore Alternative 2 west portal which appears to be located in a toppling failure landslide.

Table A-1: ISRM Classification of North Hope Peak Region Rock Units

	A - Rock Type	B - Rock Strength[1]	C - Weathering[2]	DISCONTINUITIES								L - Block Size/Shape[9]
				D - Type	E - Orientation[3]	F - Roughness[4]	G - Aperture[5]	H - Infilling Type	I - Spacing[6]	J - Persistence[7]	K - # of Sets[8]	
Red Rose Sedimentary Rocks (IK_{RS}-101 and 102)	Pyritiferous Argillite and Siltstone and Pyrite-free Sandstone	R4-R5	I - II	Joints	Jnw 300 to 311/72° NE. Jne 025 to 041/69° to 88° SE. Jflat 131 to 147/12° to 25° SW. 2 random sets	4-10	Tight	Calcite	Close	Very High	VII - VIII	Medium-sized Blocks
Telkwa Volcanics (IJTM-104)	Meta-Basalt and Meta-Andesite Flows	R5-R6	I - II	Faults, Joints	Jnw 300 to 311/72° NE Jne 025 to 041/69° to 88° SE Jflat 131 to 147/12° to 25° SW	6-12	Tight	None	Close to Wide	Low to Very High	VI	Medium-sized Blocks
Nimbus Pluton (Tgd-105)	Granodiorite	R5	I - II	Faults, Joints	Jnw 300 to 311/72° NE. Jne 025 to 041/69° to 88° SE. Jflat 131 to 147/12° to 25° SW	10-16	Tight	None	Close to Wide	Low to Very High	VI	Medium-sized Blocks
Closely Fractured Nimbus Pluton (Tgd-107)	Granodiorite	R3	I - II	Faults, Joints	Jnw 300 to 311/72° NE. Jne 025 to 041/69° to 88° SE. Jflat 131 to 147/12° to 25° SW	4-10	Partly Open	Calcite	Extremely Close to Close	Low to Very High	VI	Very Small Blocks
Hydrothermally Altered Closely Fractured Nimbus Pluton (Tqmd-108)	Hydrothermally Altered Quartz Monzodiorite	R3-R4	I - II	Faults, Joints	Jnw 300 to 311/72° NE. Jne 025 to 041/69° to 88° SE. Jflat 131 to 147/12° to 25° SW	4-10	Partly Open	Calcite	Extremely Close to Close	Low to Very High	VI	Very Small Blocks
Closely Fractured Telkwa Volcanics (IJTM-110)	Meta-Basalt and Meta-Andesite Flows	R2-R3	I - II	Faults, Joints	Jnw 300 to 311/72° NE. Jne 025 to 041/69° to 88° SE. Jflat 131 to 147/12° to 25° SW	4-10	Partly Open	Calcite	Extremely Close to Close	Low to Very High	VI	Very Small Blocks
		[1]From Table II.3 of Wyllie & Mah	[2]From Table II.4 of Wyllie & Mah		[3]Strike/Dip and dip direction	[4]From Figure II.3 of Wyllie & Mah	[5]From Table II.6 of Wyllie & Mah		[6]From Table II.7 of Wyllie & Mah	[7]From Table II.8 of Wyllie & Mah	[8]From P390 of Wyllie & Mah	[9]From Table II.9 of Wyllie & Mah

A.2 Nimbus Mountain Domains

A.2.1 Telkwa Volcanics in Nimbus Mountain area (IJTM-201)

- This domain comprises the Lower to Middle Jurassic Telkwa Formation volcanic rocks identified in the Nimbus Mountain Region, typically exposed across the surface of most of the Nimbus Mountain area, but projected to be encountered at depth only at the eastern ends of the proposed tunnel alignments.
- The relatively intact rock consists of fine-grained, igneous volcanic rocks (breccias and tuffs), typically defined as meta-andesite lithic tuff with some phyllitic partings.
- Andesite typically has a quartz and feldspar mineral component greater than 50%. Quartz grains are generally expected to be very fine grained in this rock type.
- The Nimbus Mountain Telkwa Volcanics are cut by andesite and basalt dykes (as at North Hope Peak) that are between about 0.5 m to 10 m thick, have a northwest-southeast strike (assumed similar orientation to North Hope Peak dykes) at about 310° strike with an average dip of between 80° and 90° to the NE. The dykes are typically frozen to the host rock (i.e., joints are not open), appear to pre-date the significant faulting, and post-date the placement of plutonic rocks as evidenced by their displacements and persistence across regional geological contacts.
- Felsite dykes are also present in this unit. Felsite is a rock containing a high quartz and feldspar content. The felsite dykes appear to be between 5 m and 20 m thick, sub-horizontal or sub-vertical, and have strikes near 300° (roughly sub-parallel to the tunnel axes); thus, if a felsite dike is encountered in the tunnel, it could run along the alignment for a significant distance.
- The mineralogical potential for this unit to contain appreciable sulphide bearing zones that would indicate a potential for ARD/ML issues is low; however, the ARD/ML surface work found a few areas that may have local issues (see discussion in report under separate cover).
- The unconfined compressive strength (UCS) of the intact Telkwa Formation rock is projected to be very high. In the absence of other data, this was based on projection from Telkwa rocks in the North Hope Peak area; however, there is some difference in the geology, as discussed above. A further caution is that not all Telkwa rock is strong – for example, the Clore Canyon was apparently eroded through Telkwa rock that is locally weak. The projected strength could be higher than the actual strength.
- The Telkwa Volcanics in the Nimbus Mountain area were observed in surface outcrop only, but are considered a favourable rock unit for advancement of tunnelling using TBM or drill and blast methods. The rock is relatively fine grained and is projected to correspond to a very strong rock in the ISRM classification system, subject to the discussion above.

A.2.2 Nimbus Fault (Fnb-203)

- The sub-vertical, northwest trending Nimbus Fault cuts through all of the geological units in the Nimbus Mountain Region.
- Fault movement was estimated to be on the order of 15 m where it was observed cutting a felsite dyke on surface. The true width of the fault damage zone is estimated to be about 15 m.
- The fault trace intersects the proposed Hoult Alternative 1 and Hoult Tunnel tunnel axes at relative angles between about 30° and 35° from the tunnel heading, resulting in a total intersection length along a hypothetical 5 m circular tunnel of between 34 and 40 m.

A.2.3 Bulkley Intrusives Plutonic Rock (LKg-202)

- This domain comprises the Late Cretaceous Bulkley Intrusion plutonic rocks identified in the Nimbus Mountain Region, generally exposed on surface on the west side of the mountain and underlying the Telkwa Volcanics through the "heart" of Nimbus Mountain.
- The intact rock is Late Cretaceous age, uniform, leucocratic (i.e. <10% mafic minerals and quartz-rich), fine- to medium-grained, plutonic intrusive rock that has undergone low grade metamorphism. The rock is typically made up of meta-tonalite, meta-quartz diorite and meta-alaskite. The low grade metamorphism has resulted in recrystallization within the rock, which has increased the mineral intergrowth in the micro rock fabric, resulting in increased rock strength.
- The Nimbus Mountain Late Cretaceous Plutonic Rocks are cut by andesite, basalt and felsite dykes. The mineralogy and orientations are similar to those discussed above for domain lJTM-201. In particular, note the presence of high quartz content felsite dikes that are subparallel to the tunnel axes.
- The mineralogical potential for this unit to contain appreciable sulphide bearing zones that would indicate a potential for ARD/ML issues is very low.
- The Bulkley Intrusives remain unexplored at depth. For the purposes of this report, the rock is considered to have a relatively high UCS (estimated from Point Load tests only) and favourable structure that will require little support for either TBM or drill and blast tunnelling. The rock is considered brittle, and may be subject to brittle fracture under high stress conditions.

A.2.4 Breccia Pipe (Tbx-204)

- The breccia pipe cuts through the plutonic units and may or may not intersect the surface. Surface outcrops of the pipe have not been identified to date; however, the presence of the pipe was not suspected until the core was analysed in detail well after the completion of the geology field mapping in 2006.
- The breccia is clast-supported with clasts made up of the Late Cretaceous intrusions, Telkwa metavolcanic rocks, and felsite. The clasts range from angular to subrounded and were found up to 0.1m in length. In one zone, the clasts were nearly all destroyed due to intense fragmentation of the Late Cretaceous meta-alaskite, leaving only rounded quartz and feldspar grains in a fine matrix.

- Based on the probable Tertiary age of the pipe (i.e., post-tectonic), it likely is sub-vertical. The downhole change from angular to milled breccia and ultimately to granulation of the meta-Alaskite at the bottom of DH06-NS1 indicates that the hole was directed toward the center of the pipe.

A.2.5 Gully Fault (Fgl-205)

- The northwest trending Gully Fault cuts through the geological units on the west side of the Nimbus Mountain Region.
- The fault is sub-vertical, and trends northwesterly, with the fault trace disappearing to the southeast under a glacier on the upper flanks of Nimbus Peak. Unlike all of the other major faults, the Gully Fault has not been identified along the south side of the Nimbus Mountain area.
- Fault movement is estimated to be on the order of 200 m based on an apparent offset of the Telkwa-Bulkley Intrusives contact (i.e. contact between lJTM-201 and LKg-202.
- The true width of the fault damage zone is estimated to be relatively narrow at about 3 m.
- The fault trace intersects the proposed Hoult Tunnel and possibly the Hoult Alternative 1 axes at a relative angle of about 20° from the tunnel heading, resulting in a total intersection length along a hypothetical 5 m circular tunnel of about 24 m.

Table A-2: ISRM Classification of Nimbus Mountain Region Rock Units

	A - Rock Type	B - Rock Strength[1]	C - Weathering[2]	DISCONTINUITIES								L - Block Size/Shape[9]
				D - Type	E - Orientation[3]	F - Roughness[4]	G - Aperture[5]	H - Infilling Type	I - Spacing[6]	J - Persistence[7]	K - # of Sets[8]	
Telkwa Volcanics (IJTM-201)	Meta-Andesite Lithic Tuff	R5	I - II	Faults, Joints	Jnw 320 to 330/84° to 85° NE. Jne 038 to 042/71° to 74° SE. Jflat 050 to 090/5° to 8° SW. 2 random sets	8-14	Tight to Partly Open	None to calcite	Close to Very Wide	Low to Very High	VII - VIII	Medium-size to Small Blocks
Bulkley Intrusives Plutonic Rock (LKg-202)	Meta-Tonalite, Meta-Quartz Diorite, Meta-Alaskite	R5	I - II	Faults, Joints	Jnw 320 to 330/84° to 85° NE. Jne 038 to 042/71° to 74° SE. Jflat 050 to 090/5° to 8° SW. 2 random sets	8-14	Tight to Partly Open	None to calcite	Close to Very Wide	Low to Very High	VII - VIII	Medium-size to Small Blocks
Breccia Pipe (Tbx-204)	Breccia of Meta-Tonalite, Meta-Andesite and Felsite Clasts	R4	I - II	Joints	No discontinuities recorded, structure assumed to be similar to adjacent wall rock	8-14	Tight to Partly Open	None to calcite	Close to Very Wide	Low to Very High	VII - VIII	Medium-size to Small Blocks
		[1]From Table II.3 of Wyllie & Mah	[2]From Table II.4 of Wyllie & Mah		[3]Strike/Dip and dip direction	[4]From Figure II.3 of Wyllie & Mah	[5]From Table II.6 of Wyllie & Mah		[6]From Table II.7 of Wyllie & Mah	[7]From Table II.8 of Wyllie & Mah	[8]From P390 of Wyllie & Mah	[9]From Table II.9 of Wyllie & Mah

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PRELIMINARY GEOTECHNICAL REPORT
PROPOSED KITIMAT TERMINAL
ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT, BRITISH COLUMBIA

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IMPORTANT NOTICE

This report was prepared exclusively for Northern Gateway Pipelines Inc. by AMEC Earth & Environmental Limited, a wholly owned subsidiary of AMEC. The quality of information, conclusions and estimates contained herein is consistent with the level of effort involved in AMEC services and based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions and qualifications set forth in this report. This report is intended to be used by Enbridge Inc. and firms associated with the project only, subject to the terms and conditions of its contract between Enbridge Inc. and AMEC. Any other use of, or reliance on, this report by any third party is at that party's sole risk.

EXECUTIVE SUMMARY

AMEC Earth & Environmental was retained by Northern Gateway Pipelines Inc. to provide geotechnical engineering services in support of the analysis and preliminary design of a crude oil and condensate terminal to be constructed adjacent to Douglas Channel, about 5 km south of Kitimat, BC. This report presents the findings of the preliminary geotechnical investigation carried out by AMEC, proposes a geological model of the area, and provides comments and considerations for the proposed development of the site.

The objective for this preliminary geotechnical report was to summarize collected desktop and field data and to discuss preliminary geotechnical considerations and comments.

The terrain is characterized by steep and irregular bedrock-controlled slopes that are covered by relatively thin variable soil deposits and separated by gently sloping plains that are underlain by thick deposits of glaciomarine silt and clay. The thick soil deposits mask an irregular underlying bedrock surface. The soils covering the bedrock on the steep slopes are typically mixed sands, gravels, silts, or till. Based on the geologic model, marine clay deposits of significant depth and aerial extent appear to be located below approximately 150m asl. The bedrock is variable but typically strong to very strong.

An existing 6 km long single-lane forestry road that extends south from Haisla Boulevard in Kitimat is the only land-based access to the area.

The climate is temperate and wet, typical of Coastal British Columbia.

The geotechnical investigation work to date included:

- Site reconnaissance and bedrock mapping;
- Site survey and LiDAR;
- Drilling, test pitting, in-situ testing and sampling (soil and rock drilling, vane shear tests and cone penetration tests);
- Geophysical surveys; and,
- Laboratory testing.

It is noted that the investigations to date have been for the purposes of evaluating feasibility of the preliminary concepts. Additional investigations will be required prior to final detailed design or construction.

Issues and geotechnical conditions that could impact the proposed design, facility arrangements, and/or construction include the terrain, weak marine clay, and tsunami potential. Comments are made on the tank farm area, marine clay disposal and foreshore developments.

Note that this report is relative to the terrestrial site development activities only and therefore excludes issues relating to development in the marine environment.

1.0 INTRODUCTION

1.1 General

AMEC Earth & Environmental (AMEC) was retained by Northern Gateway Pipelines Inc. to provide geotechnical engineering services in support of the geotechnical analysis and preliminary design of a crude oil and condensate terminal to be constructed adjacent to Douglas Channel, about 5 km south of Kitimat, BC.

The general location of the proposed terminal site is shown on Drawing 1. The study area is shown on an inset in Drawing 2. Photos 1 to 4 show the general site layout.

A site development plan was provided by Northern Gateway Pipelines Inc.'s civil designer, WorleyParsons (formerly Colt Engineering), and is included in Appendix A for reference.

The purpose of this report is to support the Enbridge Northern Gateway Project National Energy Board (NEB) submission by providing preliminary geotechnical considerations and comments for the proposed Kitimat Terminal site development.

1.2 Scope of Preliminary Geotechnical Study

The objective of the preliminary geotechnical study of the proposed Kitimat Terminal was to collect information to support geotechnical analysis of the proposed site developments. The geotechnical study included the following components:

- Collection of background information regarding climate, topography and geology.
- Site investigations from 2004 to 2006 including: ground and aerial reconnaissance, LiDAR, site surveying, bedrock mapping, geophysics, test pit excavation, and drilling including retrieval of samples for use in geotechnical and environmental testing.
- Laboratory testing on selected samples taken during site investigations.
- Creation of a geological model based on review and analysis of collected data.
- Formulation of geotechnical considerations and comments.

1.3 Facility Description

The proposed Kitimat Terminal will include facilities for the receipt, storage, and transfer of exported crude oil and imported condensate between the Enbridge Northern Gateway Project and ships at adjacent ship berths. A site plan that includes the proposed terminal facilities is shown on WorleyParsons Drawing 08C7138-SK-A-218 I-1, dated 20 October, 2009, included in Appendix A. Additional information about the Kitimat Terminal facility is provided in Volume 3 of the NEB application.

1.4 Existing Access Road

The Bish Forest Service Road (FSR) starts at Haisla Boulevard near the Alcan Plant in Kitimat and runs south along the west valley wall of the Douglas Channel. The existing road consists of a rough, single-lane forest access road that appears to have uncontrolled tight radius vertical and horizontal curves. Selected characteristics of the road are shown on Photos 5 to 25. The

road crosses steep, east facing, irregular bedrock-controlled slopes with frequent surface drainage channels and small streams. Note that the existing road operations require the use of radio control between vehicles to coordinate the use of pull-outs and improve safety.

Typical forestry road construction practice in the area would include poor subgrade preparation (organics below surfacing and in the toe support of most fills), the use of locally excavated (unprocessed) materials, and variable track compaction (no vibratory compaction of fill materials). It is expected that the access road has been constructed in this typical fashion. Surfacing appears to consist of locally borrowed shot-rock and gravel. The road surface is rough with boulder and cobble exposures. Based on aerial photographs, the development of roads and logging in the study area occurred between 1990 (no development) and 1997 (such that the extent of the current clearing within the study area is consistent with the 1997 and 2008 imagery).

2.0 SITE CONDITIONS

Background information, including climate data, topography, regional geological mapping, and site geology is summarized below.

2.1 Climate

Published Climate Normals (Environment Canada 1971-2000) for two weather stations at Kitimat (by international convention, normals are compiled for the last 3 decades, in this case from 1971 to 2000) show that the region is temperate and wet, typical of Coastal British Columbia. Table B-1 in Appendix B contains more climate information. Specific characteristics of note are:

- Average total annual precipitation was between 2200 and 2700 mm/year. Figures B-1 and B-2 show distributions of rainfall and snowfall throughout the year, respectively.
- Extreme daily rainfall was 180 mm.
- Extreme daily snowfall was 112.3 cm.
- Average monthly precipitation was less than 200 mm only for the period between April and August, and approached 300 to 400 mm per month for the period of October to December.
- Temperature extremes ranged from a low of -26°C to almost 37°C. Figure B-3 shows the distribution of daily average temperature throughout the year.

2.2 Topography

The site is about 275 ha in size, and has a total vertical relief of up to 220 m. Significant steep and irregular slope areas prevail with frequent bedrock exposures, particularly along the site access roads. On steeper slopes, the topographic relief is more abrupt as compared to the more subdued gentle slopes. The gentler sloping areas (such as in the north and west-central portions of the site) are believed to be underlain by irregular bedrock surfaces masked by discontinuous mixed soil deposits such as sand, gravel, till or clay. Soils are discussed in detail in Section 4.0, below.

Flat to gentle plateaus with little to no relief are located on the east-central, central, and south-central portions of the site. These features are located adjacent to (above and below) steep irregular slopes. The flat areas are interpreted to be the surfaces of clay deposits that mask the underlying irregular bedrock surface.

2.3 Published Geology and Aerial Photography

A review of published bedrock geological information (BC Ministry of Energy and Mines), and aerial photographs was conducted by AMEC.

Published surficial geology is not available for the project site, although a significant regional study was carried out by Clague (1984) that covers areas immediately north of the project site at Kitimat. The Clague study stated that the terrain in the vicinity of the project area was subjected to about 200 m of uplift relative to the current sea level due to unloading following de-glaciation of the region. This uplift caused the emergence of marine-deposited sediments adjacent to coastal areas, particularly marine clay deposits. As a large majority of the proposed Kitimat terminal is below 200 m elevation, this would suggest that soil deposits at the terminal site may also be of marine origin. Clague (1984) indicated that marine clay sediments were deposited in a pro-glacial environment and were generally gullied and terraced. Clague also indicated that thin patchy marine sediments with little or no independent surface expression overlie bedrock and unconsolidated sediments in many areas.

Marine sediments deposited in a pro-glacial environment would often be normally consolidated (NC)[1], and as a result would typically have low shear strength, high compressibility, and low bulk permeability. As a result of isostatic rebound following deglaciation, the regional soil deposits have been raised above sea level. For marine clay deposits subjected to such rebound conditions, leaching with fresh groundwater may result in formation of a sensitive (or possibly quick) condition such that the clay may undergo significant strength losses as a result of stress change due to shearing or additional static loading. Sensitive, or quick, is defined as follows: "sensitive" means the clay has a ratio of peak to residual shear strength >4 while "quick" clays have a ratio of peak to residual shear strength of >30, (almost complete loss of strength). The large contrast between intact and remolded strength can present a significant geological hazard due to abrupt loss of peak strength, possibly as a result of minor disturbance or time-related leaching of the clay. In the worst cases where quick clay exists, the strength loss can change the clay to a material that flows as a viscous fluid. In contrast, sensitive clays would retain some level of strength and would not flow as a viscous fluid. Collapse of the soil structure is typically manifested as low angle, retrogressive failures. Care should be taken in designing facilities on or below areas containing marine clay soil deposits.

A literature review of bedrock geology indicated that bedrock at the site consists of Coast Plutonic quartz dioritic igneous rocks of Late Cretaceous to Middle Jurassic age (100 million to 150 million years old). Quartz diorite is typically a very strong rock, generally requiring drill and blast excavation techniques.

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[1] Normally consolidated – When the present effective stress is the maximum to which a clay has ever been subjected. (Craig 2004)

Review of aerial photography for the project site indicated that the area was covered by a variable thickness of fine-grained soil that masked an underlying irregular bedrock surface. Flat to gently sloping plateaus indicated areas of thicker soils (blanket deposits masking underlying topography), while other areas of irregular terrain suggested thinner soil deposits (veneer deposits) over bedrock. It was difficult to determine the detailed distribution of the thicker soil deposits, perhaps due to the soils overlying very rough and intricate bedrock topography.

Fine-grained soils were indicated by gullied erosion patterns that extended down from plateaus to the streams on the west side of the study area, and to the ocean on the east side of the area. The plateaus were interpreted as areas underlain by marine clay deposits. While the terrain throughout the site contained irregular slopes, the plateau deposits appeared to be located below about 150 m elevation. The terrain above about 150 m elevation was characterized as rolling to irregular. Linear trends in vegetation patterns in the north central portion of the site suggested bedrock-controlled topography with shallow soil cover.

3.0 SITE INVESTIGATIONS

The following work was carried out between 2004 and 2006 at the project site. Locations are shown on Drawing 2:

- Two LiDAR surveys to establish a terrain model;
- A ground-based site survey (approximately 32 km) to establish a project control network and provide profiles of geophysical lines for the concurrent geophysical surveying;
- Bedrock mapping to collect bedrock descriptions and structural measurements (mapping data in Appendix C);
- Geophysical surveys (approximately 32 km) to estimate the depth of overburden soils and to provide a profile of the underlying bedrock surface along each line;
- Excavation of nine test pits (designated by the prefix 'TP') to identify shallow soil conditions and bedrock depths at select sites inaccessible to drill equipment (test pit logs in Appendix D);
- Drilling of 24 drill holes (designated by the prefix 'DH') to investigate soil conditions and determine the depth to and condition of bedrock. Geotechnical and environmental sampling were carried out (drill logs and core photos in Appendix D); and,
- Cone Penetration Tests (CPT) and Vane Shear Tests (VST) at six drill hole locations to characterize the marine clay unit (CPT and VST data in Appendix D).

Following the site investigations, laboratory testing was completed on select soil and rock samples. Test results are summarized throughout this report.

4.0 GEOLOGICAL MODEL

In descending order, the geological units observed within the investigated areas of the site generally consisted of fill (in roadway areas), topsoil, marine silt or clay, sand or sand and gravel, and bedrock. Some till was encountered in localized areas above the bedrock. Descriptions of the encountered soil units are provided in the following sections.

Subsurface descriptions are based on site observations, testing, or interpretation of information gathered from drilling, test pit excavation, bedrock outcrop mapping, and geophysical surveying. Note that due to the thick vegetation cover and rough topography, relatively few drill holes and test pit excavations have been completed to-date, considering the size of the site.

4.1 Fill

Fill was observed at 14 locations where boreholes/test pits were advanced through the existing roadways. Road fill at the site generally consists of coarse, angular shot-rock. Typically, the thickness of the road fill varied from about 0.2 to 1.2 m, with an average of 0.6 m.

4.2 Topsoil

The forest topsoil (organic soil) thickness was variable across the site, generally ranging from about 0.5 m to 1 m, with a maximum of 2 m, where investigated. The topsoil layers appeared continuous and were encountered in test pits and drill holes throughout the site.

4.3 Marine Clay (or Silt)

Significant portions of the site are underlain by mineral soils consisting of firm to stiff, low to medium plastic clay. Table 4-1 gives the index properties of the clay based on field and laboratory testing. The clay was determined to be of marine origin based on the elevation of the deposits, nearby geological mapping, and comparison of the measured index properties with published index properties of marine clays from the region (Geertsema and Torrance 2005). At the site, marine clay was typically encountered underlying flat to gently sloping terrain units; and was found below elevation 150 m at TP05-1, 3, 5, and 8; DH05-1, 2, 4 to 6; and at DH06-1, 3 to 8, 10, and 24. The marine clay encountered in the drill holes and test pits varied widely from 1 to 26 m in thickness, generally with a stiffer 3 to 5 m thick “crust” at the top of the unit.

As described in Section 2.3, above, marine clay is typically expected to have properties of variably low shear strength, low bulk permeability, relatively high compressibility, and variable sensitivity ranging to high. A wide range of strengths was found in the marine clay profile, which appears to be typical of the Kitimat area. Vane Shear Testing (VST) data shows that the undrained shear strength of the clay generally decreases with depth. Based on the estimated pre-consolidation pressures, the marine clay, below the crust, appears to be normally consolidated.

Regional information (described in Section 2.3, above) indicated the potential for marine clay deposits to occur in the region below an elevation of about 200 m above present sea level due to relative sea level adjustments since the last glaciation. The results of site investigations and laboratory testing, as presented above, confirm this, however, no significant intersections of clay

were encountered above 150 m elevation. It is important to keep in mind the wide spacing of the site investigations conducted to date.

Based on the laboratory test results presented above, sensitive clay (maximum sensitivity of 10.3) was identified beneath the clay crust, but quick clay has not been identified.

Table 4.1: Index Properties of Marine Clay

Test Method	Property	Depth	Values
SPT	'N' Value	Crust (3-5 m)	14 to 52
		Below crust	3 to 15
CPT	Total Tip Resistance	Crust (3-5 m)	60 to 80 bar[2]
		Below crust	Below 20 bar
	Friction Ratio	Crust (3-5 m)	4 to 6%, with peaks over 10%
		Below crust	Below 3%
VST	Shear Strength	Crust (3-5 m)	Maximum 180 kPa
		Below crust	Minimum 30 kPa (decreases with depth)
	Sensitivity	Above 10 m	1.2 to 3.5 (not sensitive)
		Below 10 m	1.4 to 10.3 (not sensitive to sensitive)
	Cone Factor Value (Nkt)[3]	Entire thickness	7 to 13
	Remoulded Strength	Below crust	As low as 2.5 kPa
Laboratory Tests	Moisture Content	Crust (3-5 m)	17 to 29%
		Below crust	13 to 35%
	Plastic Limit	Crust (3-5 m)	15 to 24%
		Below crust	14 to 20%
	Liquid Limit	Crust (3-5 m)	21 to 43%
		Below crust	20 to 37%
	Plasticity Index	Entire thickness	3 to 19% (avg. 11%)
	Hydrometer	Entire thickness	Clay 20 to 45%, Silt 40 to 75%, Fine Grained Sand 10% (clay content decreases with depth)
	Preconsolidation Pressure	Entire thickness	35 to 310 kPa
	Compression Index (Cc)	Entire thickness	0.1 to 0.4

[2] 1 bar = 100 kPa
[3] $N_{kt}=(q_t - \sigma_{vo}) / s_u$, where q_t is cone resistance corrected fore pore pressure effects, σ_{vo} is total in-situ vertical stress and s_u is undrained shear strength (Lunne, Robertson and Powell 1997)

4.4 Till

Till deposits were encountered during the 2005 geotechnical investigation at depths of between 3 and 4 m in the northwest part of the study area in Test Pits TP05-10 (elevation 175m) and TP05-11 (elevation 141m) overlying bedrock. The till was compact to dense, well graded silty sand (or sand and silt), with some gravel (to gravelly). Moisture contents ranged between 8% and 23%. Till deposits were not encountered in the 2006 geotechnical investigation, as the focus of subsurface investigations was on areas of near-surface rock above elevation 150 m. The till at this site is expected to be highly variable, and should be considered to have significant variation in grain size, moisture and relative density.

4.5 Sand and Gravel

Sand and gravel deposits were encountered over much of the site, generally underlying the marine clay and overlying bedrock. These deposits were encountered at widely varying depths ranging from 0.5 m at DH06-09 to about 28 m at DH06-03. The deposits ranged from fine- to coarse-grained, angular to rounded, compact to dense, and moist to wet, and were typically 2.6 m thick where they were encountered near surface (not underlying clay) and 5.2 m thick where they were encountered below the marine clay.

The sand and gravel stratum was also encountered in the east portion of the site in DH05-4 and DH05-4B where it was underlying the marine clay, and extended from 6.7 m depth to the bedrock surface at 20.5 m depth. From 6.7 m to 16.8 m, the deposit was dense, wet coarse-grained sand (50%) and gravel (39%), with some fines (11%), containing frequent cobbles below 14.5 m. Below 16.8 m, the deposit mainly consisted of fine- to medium-grained silty (34%) sand (58%), with trace amounts of gravel (8%).

Proportions of sand and gravel sizes varied widely from borehole to borehole and with depth. For example, particle size distributions of a sample from 4.3 m depth in DH06-1 were 3% gravel, 94% sand, and 3% fines as compared to a sample from the 19.1 m depth in DH06-10 with 30% gravel, 60% sand, 10% fines.

4.6 Bedrock

Geophysics conducted at the site indicate that the depth to bedrock at the site is highly variable, typically ranging from 0 to 10 m along survey lines with localized areas where the bedrock depth exceeded 30 m. This interpretation confirms the general reconnaissance level observations and drilling results. The greater depths to bedrock identified in the surveys are associated with the flat to gently sloping plateaus on the site.

Bedrock was encountered in surface outcrops along the access road and in the drill holes and test pits throughout the site. The bedrock is variable, and consists of a bulk mass comprising gneiss (metamorphic rock), diorite (igneous rock) and ultramafics (igneous rock), all of which are cross-cut by felsic dykes (igneous intrusive rock, occurring as veins up to several metres thick) and scattered andesite (volcanic rock) dykes. Work to date indicates that the distribution of rock types across the site is variable. All of the intrusive rock types are broadly similar to granitic rocks (except for the ultramafics observed in DH06-17), although as noted, some have gneissosity and some have higher quartz contents.

Bedrock outcrop mapping was carried out on the site in 2005 and 2006. The objective of the outcrop mapping was to add to the bedrock description and structural measurement data. The traverse notes taken during mapping in 2006 are included in Table C-1 of Appendix C. Table C-2 of Appendix C provides details of all structural measurements, including Rock Mass Rating (1989) classifications.

The results of the bedrock outcrop mapping indicated an average discontinuity spacing in the surface exposures of 0.5 m (typical minimum 0.1 m, typical maximum 3 m). The suggests the rock is heavily jointed and that the average near-surface block size (assuming a 0.5 m square pattern) would be on the order of 300 kg. Considerable variability should be expected and this figure may be on the high side since "random" joints, irregular fractures and the interaction of the joint distributions in three dimensions were not included in this preliminary analysis. Rock strength testing yielded an unconfined compressive strength of 134 MPa for intact, homogeneous rock. The rock is classified as strong to very strong (Wyllie and Mah 2004), or Grade R4 to R5 (CGS 2006). Based on field observations and measurements, the overall rock mass has an estimated Geological Strength Index (GSI) of approximately 55 to 65, indicating a fair to good quality rock mass.

The foliation in the gneiss tends to strike west-northwest to east-southeast, dipping between 40° and 80° north-northeast. The felsic dykes had several different joint sets and highly variable strikes and dips with no strong overall orientation. This variability is illustrated in Drawing 3 (which shows structural measurements across the site and a stereonet plot of the joint orientations) as well as in photos taken during outcrop mapping. A few faults were observed at various orientations.

Bedrock core was recovered using diamond drilling methods from DH06-13 to 18 and 22. The core was logged and photographed. Rock core logs and core photos are included in Appendix D. Examination of the rock core collected from DH06-13 to 18, and 24 indicated a compositional range between granodiorite and diorite/gabbro, with localized zones of metamorphic alteration generally in close proximity to felsic intrusions. Ultramafic rock was only encountered in DH06-17.

An examination of the rock core collected from DH05-1 to 3, 4B, and 6 indicated that there were widely scattered, very thin (typically less than 1 mm thick) veinlets of sulphide minerals in the gneiss. Most of the sulphide occurrences appeared to be pyrite based on visual examination. The 2006 field investigation included the collection of rock core at select locations throughout the project site. Since this work, AMEC has undertaken a separate study of Acid Rock Drainage/Metal Leaching (ARD/ML) potential for the project. The findings of ARD/ML related work at the terminal site are presented under separate cover.

4.7 Groundwater

Groundwater levels (where encountered) were recorded for drill holes and test pits across the site. Qualitative observations of long-term groundwater levels included soil moisture and inflow to drill holes and test pits (particularly in granular deposits) and soil color (grey where soil remains saturated). These observations suggest that a static groundwater table (perhaps perched) follows the terrain at a depth of between 4.5 and 5.5 m in areas with low relief. Groundwater levels were not observed in clay drill holes, as the holes were not open long enough for the water to recover. Groundwater elevations may vary appreciably during varying weather and climatic conditions.

In irregular, high relief terrain, groundwater patterns can be expected to preferentially flow along open fracture networks in the bedrock and along the overburden-bedrock contact. As a result of these structural and topographic controls on groundwater flows, it should be expected that the pattern and potential flows intersected in cuts will be highly variable as well as weather-dependent. Deep, regional groundwater patterns are expected to be within the underlying bedrock. Groundwater levels were not measured or estimated in the bedrock; however, it may be expected that ephemeral or permanent springs could occur on areas of cut and along slopes and cuts on lower parts of the site including cuts on the slopes leading down to Kitimat Arm.

5.0 GEOTECHNICAL CONSIDERATIONS AND COMMENTS FOR PROPOSED SITE DEVELOPMENT

5.1 Terrain Considerations

The rugged topography in combination with relatively great relief and granular nature of surficial soil conditions could result in geological hazards related to sliding, debris flows and rock falls. Mass movements due to sliding are a hazard associated with slopes underlain by soils or rock, and must be assessed on a case-by-case basis. Debris flows are hazards typically associated with peak stream flow events which can transport significant amounts of materials along steep stream reaches.

Protection from rock falls, which is a hazard applicable to both natural and man-made slopes, must be considered in the design of site grading works and terminal facilities. A rock fall hazard area is located on the Bish FSR (existing access road to site) at about Km 4.2. In this area, rock fall and small rock slides occur frequently and infringe on the road. The road is very narrow through this area and is constrained geometrically by steep slopes on both sides. Rock fall hazards exist at other locations across the site and along the access road as a result of boulders that are perched on the slope and, at some locations, as a result of bedrock exposures.

5.2 Marine Clay Considerations

Weak and compressible marine clay sediments are present over portions of the site, mainly the plateaus, to a wide range of depths. The decrease in strength with depth and total thickness (up to 30 m in some locations) will present particular challenges for site development as discussed below.

- **Bearing Capacity** would be very low due to the high compressibility and low shear strength of the marine clay. The marine clays would provide very limited vertical or lateral support for pile foundations.
- **Settlement** would be large in the marine clay, as it is normally consolidated, and as such would not provide a good foundation for any structure that could not tolerate settlement.
- **Liquefaction Potential** is a concern for sensitive clay and could result if the clay is loaded or disturbed.
- **Handling, transport, stockpiling and storage** of the marine clay deposits will be difficult. The combined effects of very low disturbed strengths, high sensitivities and a wet climate will also complicate disposal efforts, as the material could have little to no ability to be stockpiled to any practical self-supporting height or on an unconfined slope area. Separation of the material from the underlying deposits or rock may be difficult during excavation work.
- **Trafficability** of construction equipment will be very low as the clay will generally not support traffic loading. The deeper sensitive clays will be particularly difficult in this respect.
- **Temporary cuts** may be limited in height due to worker safety considerations, topography and the strength of the clay.
- **Slope failures** in marine clay soils can result in retrogressive, low-angle, long run-out landslides. Typically these slides are triggered by geometric and loading changes associated with excavations, erosion of material from the toe of clay slopes, or from the dynamic effects of shear-induced pore water pressure changes during an earthquake. Failure can also occur without obvious triggers.
- **Re-use of clay** will be limited. Due to its relatively low strength in a re-compacted state, higher than optimum moisture content, high sensitivity of certain deeper clay layers, excavated marine clays are not considered suitable for re-use as structural fill.
- **Sedimentation issues** are likely to arise from excavated marine clay slopes when exposed to high precipitation at the site.

5.3 Tank Farm Area

Based on the information from the test pits, drill holes, and interpreted geophysical surveys, the proposed tank farm areas are located in areas with relatively shallow bedrock where the subsurface investigations did not encounter marine clay and thus the area is suitable for the planned development. While the bedrock is interpreted to be shallow in most areas of the tank farm, it should be noted that areas of deeper bedrock exist based on a comparison of the bedrock surface and the LiDAR surface. The thin soil deposits that cover the underlying

irregular bedrock surface are expected to include sand and gravel and/or till. These soils are believed to be compact or dense, and could be suitable for the support of gravel pad foundations for tanks; however, the subsurface sampling and testing undertaken to-date in the tank farm area is very limited, and regional geological mapping suggests that marine clay deposits could exist above elevation 150 m. Marine clay could also be encountered in areas of deeper or lower elevation bedrock. Further study of the specific tank lot sites is required prior to construction to develop suitable foundation design recommendations.

5.4 Marine Clay Disposal

The marine clay will generally not be suitable for re-use on site. The excavated material could potentially be stockpiled, although this may require site specific designs to evaluate suitable pile face stability conditions. A preliminary stockpile area has been identified just north of the proposed fence line, as shown on Drawing 4. Site specific evaluation of the area is required in future project planning and design phases.

5.5 Foreshore Developments

Foreshore developments will generally be constructed on an area with thin soil deposits covering a steeply dipping, irregular bedrock profile that is roughly parallel to the surface topography. It should be expected that major jointing will be parallel to the slope face, a condition typical in deep inland fjords. Grading would be expected to produce large cuts to prepare a platform above the intertidal zone for development out to the ship berths, and as a consequence, any cuts proposed during construction will require specific slope stability assessments at the detailed design stage.

Steeply descending streams on the slopes could be subject to debris flows, although these have small catchment areas and would be of low potential impact. Debris flow assessments would be completed once a final grading plan is developed.

5.6 Tsunami Potential

Work to date suggests that the potential for a naturally occurring tsunamigenic slide in Kitimat Arm is low. Future work to confirm this preliminary assessment will include review of the likely magnitude and frequency relations for potential future tsunami events relative to the terminal facilities. Additional information is contained in Appendix E-3 Overall Geotechnical Report.

6.0 LIMITATIONS AND CONTINGENCIES

This report is intended as a preliminary geotechnical site assessment, and as such provides a general assessment rather than specific recommendations for foundations and earthworks. The report is based on the findings at widely spaced test pits and boreholes, and on geophysical test data. Considerable caution must be exercised in extrapolating the findings between test locations since the remote electronic methods used in geophysics can sometimes provide misleading results. Given the variability in the stratigraphy, and load intensities of the proposed tanks, it is recommended that a more comprehensive geotechnical investigation be undertaken for the final design.

This report has been prepared for the exclusive use of the Northern Gateway Pipelines Inc. and WorleyParsons for specific application to the project described above and is subject to the terms of AMEC's contract with Northern Gateway Pipelines Inc... It has been prepared in accordance with generally accepted soil and foundation engineering practices. No other warranty, expressed or implied, is made.

Respectfully submitted,

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Photo 1: Looking north at proposed Kitimat Terminal site.

Photo 3: Looking east at proposed Tank Farm area.

Photo 2: Looking northwest at proposed Kitimat Terminal site.

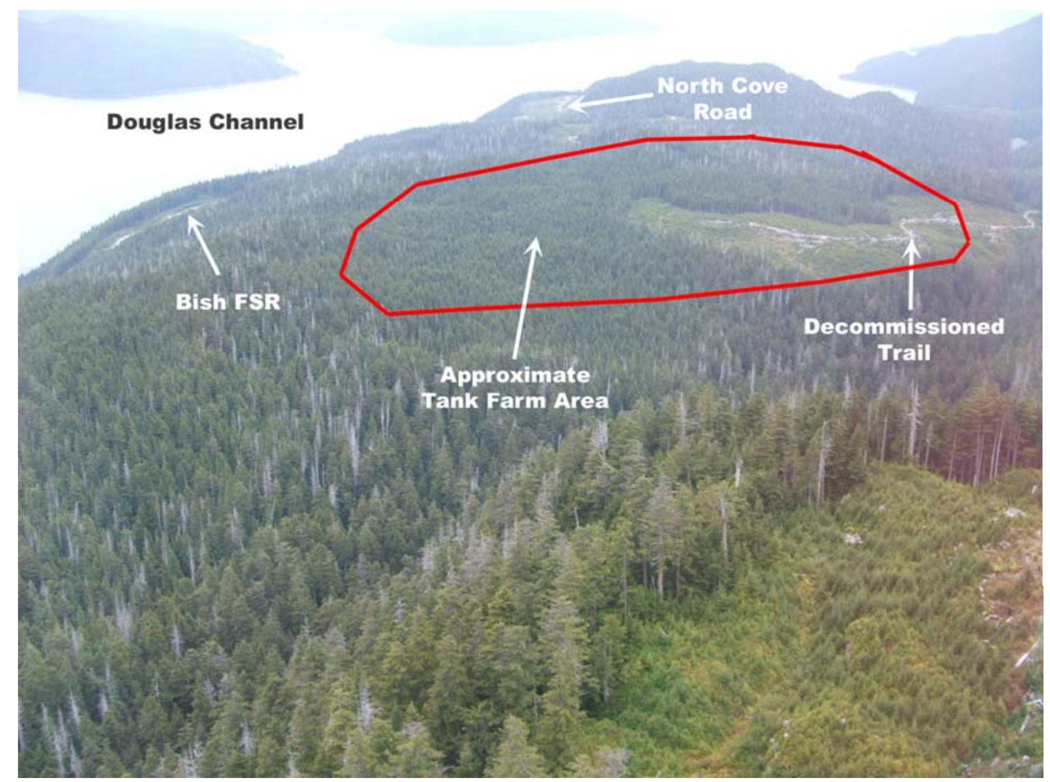

Photo 4: Looking south at proposed Tank Farm area.

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ENBRIDGE NORTHERN GATEWAY PIPELINES

Preliminary Geotechnical Report on Proposed Kitimat Terminal

NOTE: TO BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL REPORT NO. 1121-WT-20090512 DATED SEPTEMBER 9, 2009.

DATE PREPARED: SEPTEMBER 2009

REVISION: 1

PREPARED BY: H.ROBERTSON/ S.HORSLEY

PROJECT No: EG0926008.4200

Photos 1 to 4

Taken: 2005, 2008

Photo 5: View northeast along the Bish FSR from about Km 6.5.

Photo 6: View southwest along the Bish FSR from about Km 6.5.

Photo 7: View southwest along the Bish FSR from about Km 6.8.

Photo 8: View northwest along the Bish FSR from Km 7.0.

Photo 9: View west along the Bish FSR from about Km 7.2.

Photo 10: View south along the North Cove Road from the Bish FSR junction.

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REVISION: 1

PREPARED BY: H.ROBERTSON/ S.HORSLEY

PROJECT No: EG0926008.4200

Photos 5 to 10

Taken: 2005


Photo 11: View northeast along the Bish FSR from about Km 8.7. Note junction of Branch 160.


Photo 12: View south from the Branch 160 Road.


Photo 13: View north along the Branch 160 Road at about Km 0.6.


Photo 14: View southwest at end of North Cove Road.

Photo 15: View north along North Cove Road towards the Bish FSR junction.

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ENBRIDGE NORTHERN GATEWAY PIPELINES

Preliminary Geotechnical Report on Proposed Kitimat Terminal

NOTE: TO BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL REPORT No. 1121-WT-20090512 DATED SEPTEMBER 9, 2009.

DATE PREPARED: SEPTEMBER 2009

REVISION: 1

PREPARED BY: H.ROBERTSON/ S.HORSLEY

PROJECT No: EG0926008.4200

Photos 11 to 15

Taken: 2005

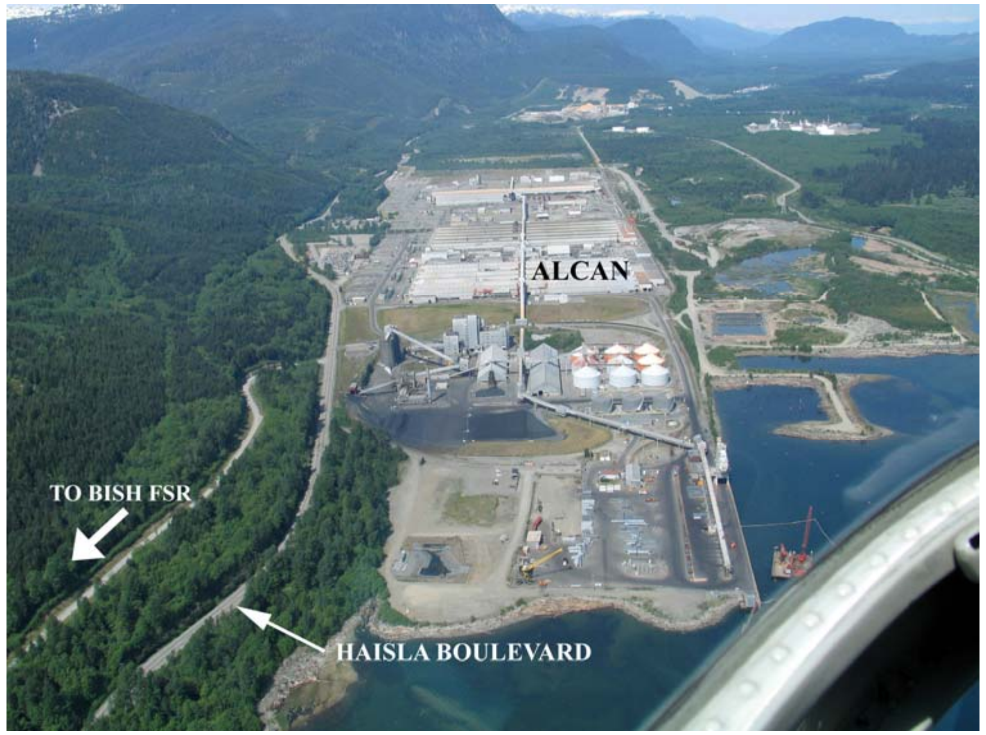

Photo 16: Looking north at Haisla Boulevard and Bish FSR Junction.

Photo 17: Looking north at KM 1 along the Bish FSR.

Photo 18: Looking north at KM 2 along the Bish FSR.

Photo 19: Looking north at KM 3 along the Bish FSR and single lane bridge.

Photo 20: Looking north at single lane bridge.
(see Photo 19)

Photo 21: Looking north at rock fall zone along the Bish FSR.

AMEC Earth & Environmental
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ENBRIDGE NORTHERN GATEWAY PIPELINES

Preliminary Geotechnical Report on Proposed Kitimat Terminal

NOTE: TO BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL REPORT No. 1121-WT-20090512 DATED SEPTEMBER 9, 2009.

DATE PREPARED: SEPTEMBER 2009

REVISION: 1

PREPARED BY: D. OSTRITCHENKO/ S.HORSLEY

PROJECT No: EG0926008.4200

Photos 16 to 21

Taken: 2005

Photo 22: Looking north at KM 5 along the Bish FSR.

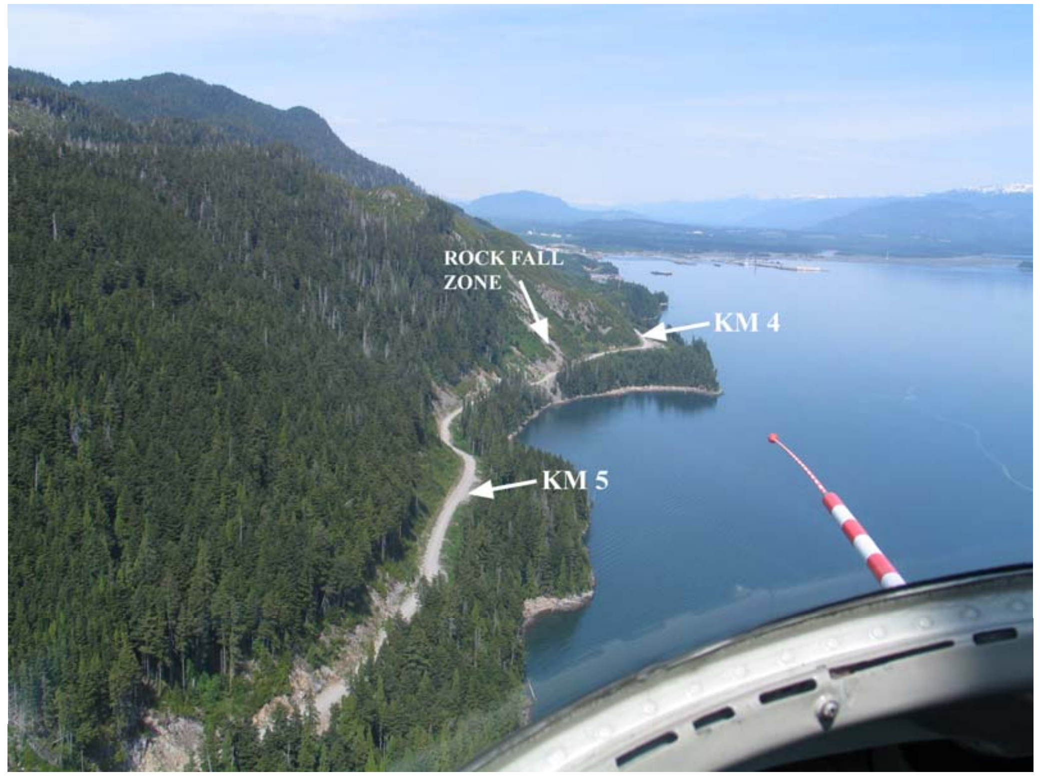

Photo 23: Looking north at KM 6 along the Bish FSR.

Photo 24: Looking south at rock fall zone.

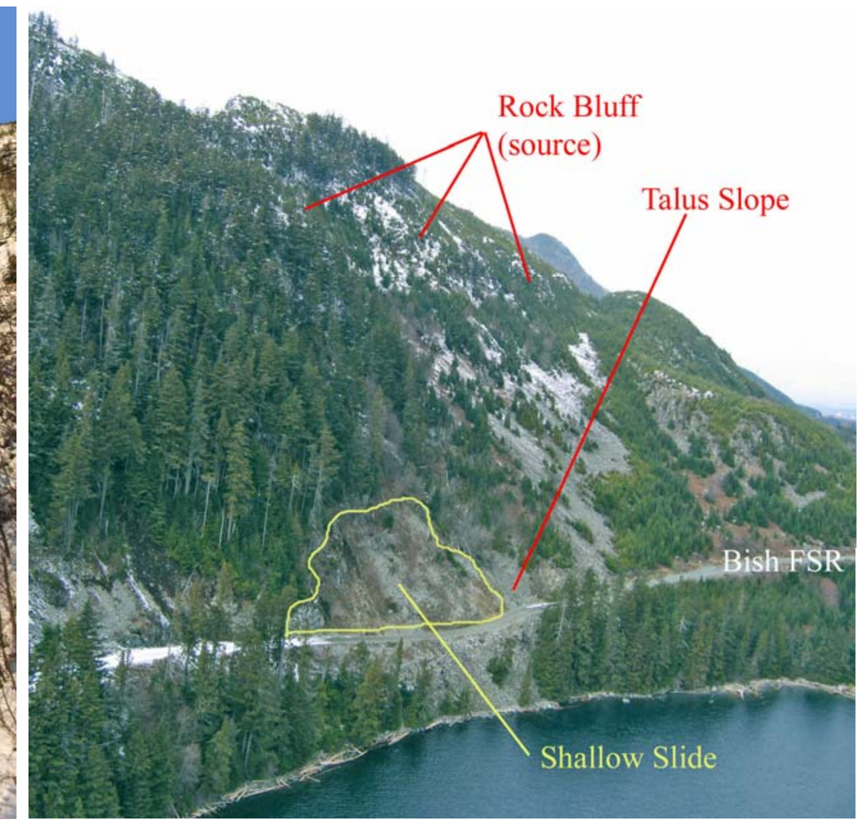

Photo 25: Looking northwest at rock fall zone.

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ENBRIDGE NORTHERN GATEWAY PIPELINES

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DATE PREPARED: SEPTEMBER 2009

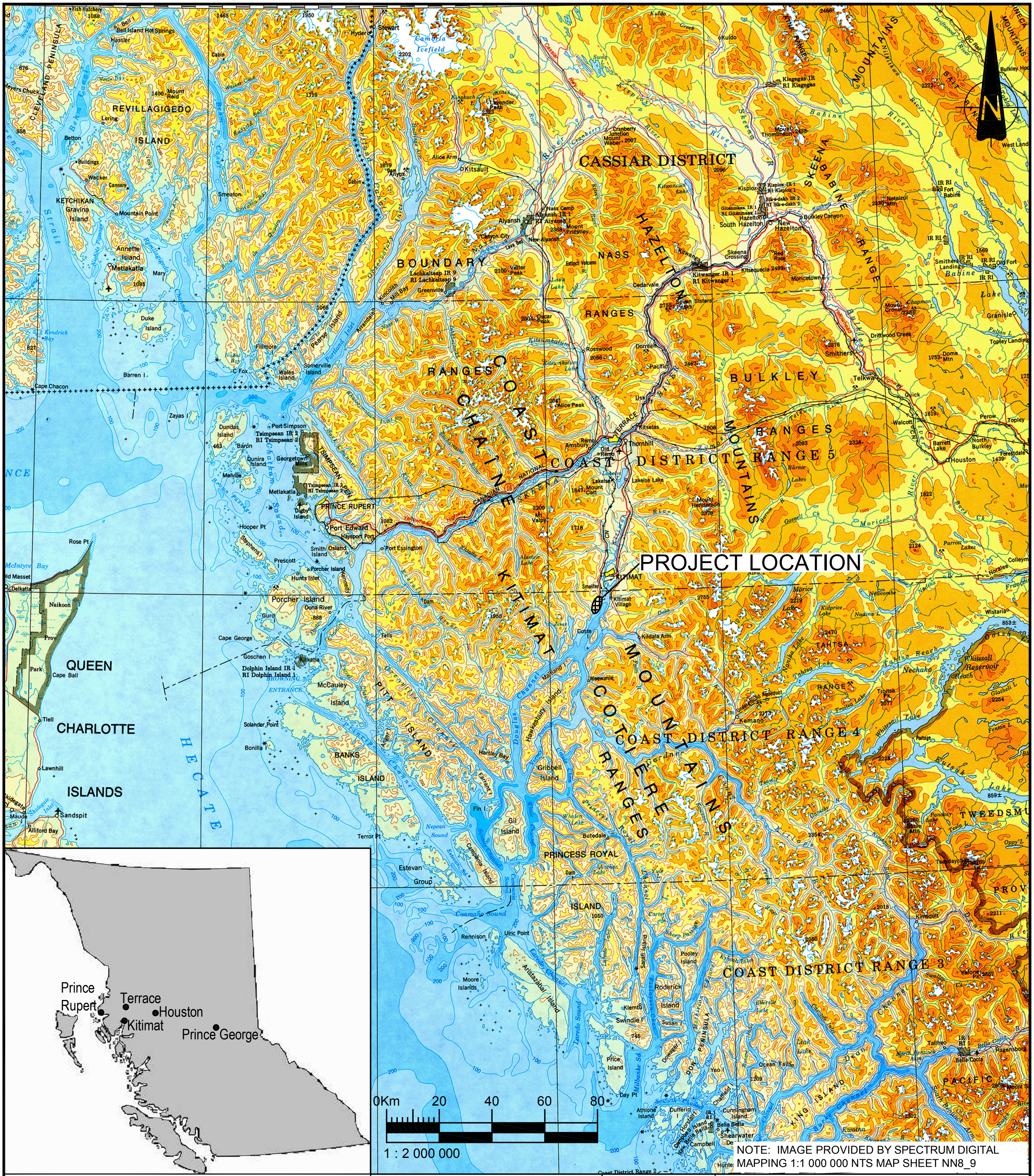
REVISION: 1

PREPARED BY: D.OSTRITCHENKO/ S.HORSLEY

PROJECT No: EG0926008.4200

Photos 22 to 25

Taken: 2005



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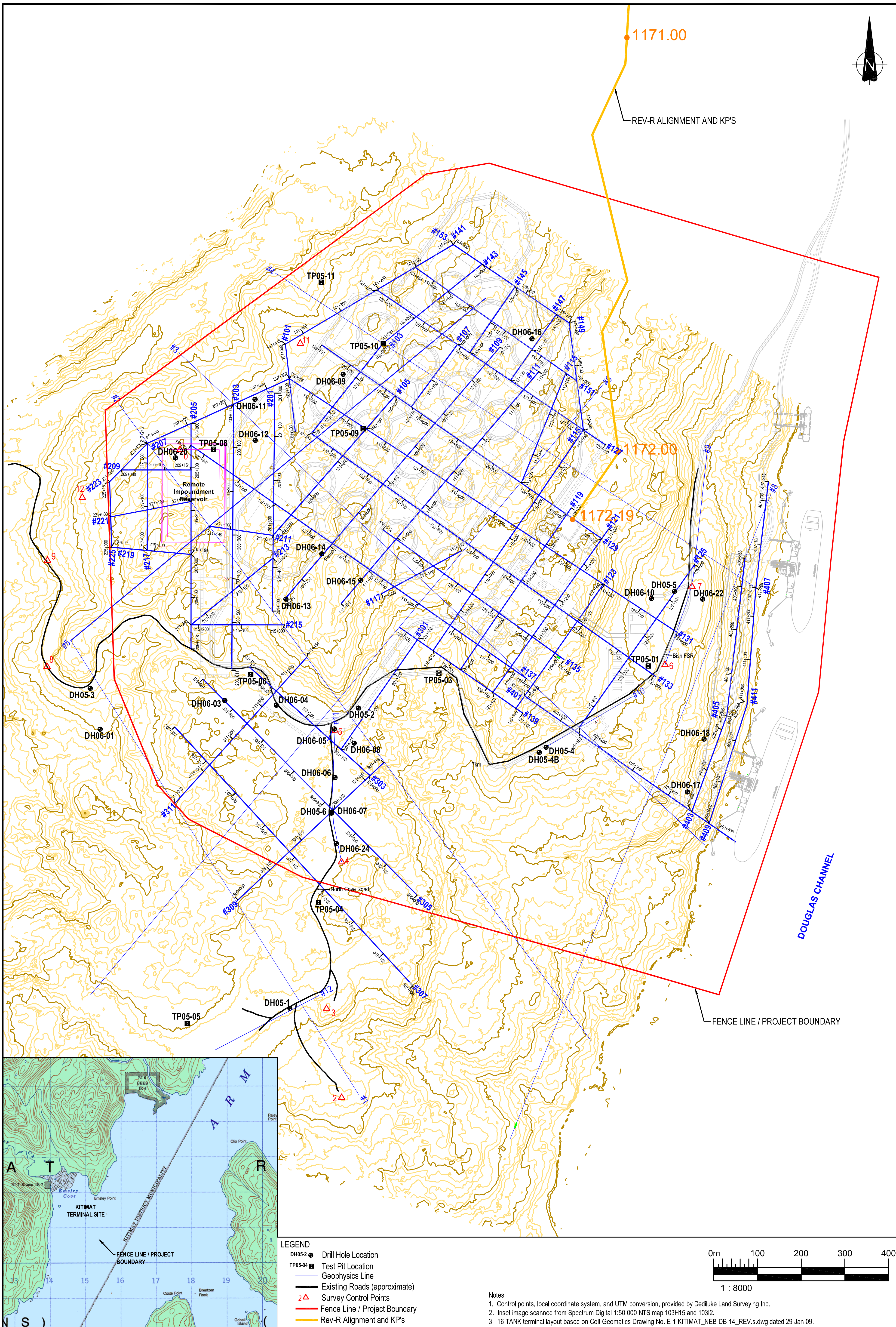
amec

CLIENT: ENBRIDGE NORTHERN GATEWAY PIPELINES

TITLE: SITE LOCATION PLAN	DWN BY: I.Macleod	DATUM: NAD83	DATE: SEPTEMBER 2009
PROJECT: PRELIMINARY GEOTECHNICAL REPORT ON PROPOSED KITIMAT TERMINAL	CHK'D BY: S.Kelly	REV. NO.: B	PROJECT NO: EG0926008.4200
	PROJECTION: UTM Zone 9	SCALE: 1: 2 000 000	FIGURE No. DRAWING 1

S:\DRAFTING\Out Of Office – Drafting\For DVD\EG0926008.4200–Drafting\EG09260.4200–Drawing1–SLP.dwg – FIG1 – Sep. 11, 2009 2:14pm – ian.j.macleod



LEGEND

- DH05-2 Drill Hole Location
- TP05-04 Test Pit Location
- Geophysics Line
- Existing Roads (approximate)
- 2 Survey Control Points
- Fence Line / Project Boundary
- Rev-R Alignment and KP's

0m 100 200 300 400

1 : 8000

Notes:
1. Control points, local coordinate system, and UTM conversion, provided by Dediluke Land Surveying Inc.
2. Inset image scanned from Spectrum Digital 1:50 000 NTS map 103H15 and 103I2.
3. 16 TANK terminal layout based on Colt Geomatics Drawing No. E-1 KITIMAT_NEB-DB-14_REV.s.dwg dated 29-Jan-09.

REV	D	M	Y	ISSUE/REVISION DESCRIPTION	ENG.	APPR.
B	9	9	09	ISSUED AS FINAL FOR NEB	DSC	SK
A	16	6	09	ISSUED AS FINAL	DSC	SK

Client: ENBRIDGE NORTHERN GATEWAY PIPELINES

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amec

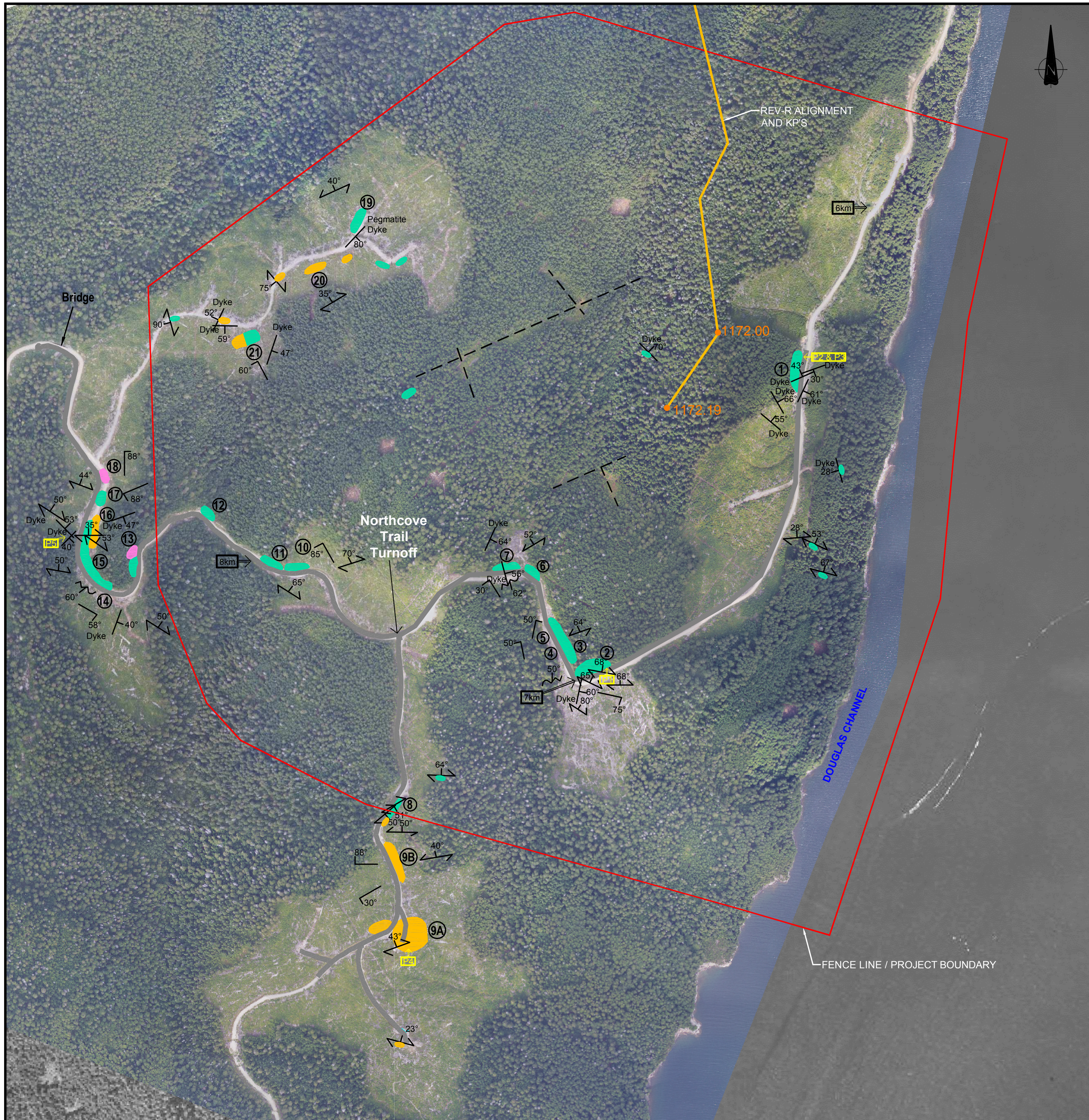
DATUM:	NAD83
PROJECTION:	UTM Zone 9
DRAWN BY:	I.Macleod
REVIEWED BY:	S.Kelly
ORIGINAL SCALE:	1:8000

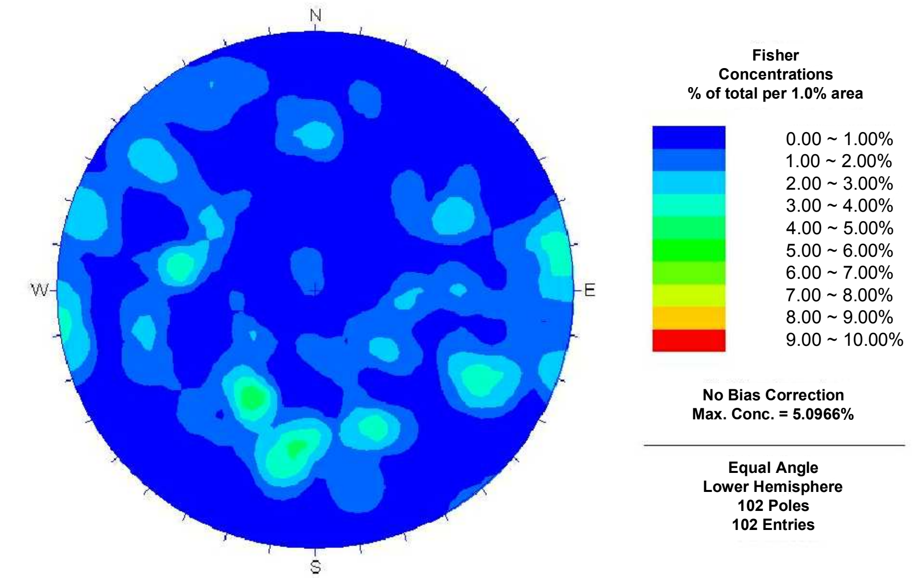
TITLE: GENERAL SITE PLAN

PROJECT: PRELIMINARY GEOTECHNICAL REPORT ON PROPOSED KITIMAT TERMINAL

PROJECT NO.:	EG0926008.4200
REVISION NO.	B
DATE:	SEPTEMBER 2009
FIGURE NO.:	DRAWING 2
SHEET NO.:	1 of 1

This drawing was originally produced in colour.





CONTOURED STEREONET SHOWING OVERALL JOINT ORIENTATIONS

Photo 1: Contact between felsic dyke and gneiss.

Photo 2: Minor sulphides on gneiss surface.

Photo 3: Felsic dykes in gneiss.

Photo 4: Quartz diorite outcrop.

Photo 5: Quartz diorite dykes in gneiss.

LEGEND

- Road and Trails
- Gneiss (with dykes of Unit 3)
- Foliated Quartz Diorite/Diorite (with dykes)
- Felsic Dykes
- Outcrop Number
- 50° Strike and Dip (dykes)
- 50° Foliation
- 50° Fractures
- 50° Fault
- Bedrock Lineations from airphoto
- P1 Photo location and direction (shown in yellow on figure)
- Rev-R Alignment and KP's

NOTES:

1. Black & White Airphoto scanned from 1997 Aerial Photograph SRS5819#203, obtained from West Fraser, Terrace, BC.
2. Detailed Aerial photos from Colt Geomatics (data custodians for GEMS / Enbridge).
3. Outcrop margins shown are approximate, obtained from air photo interpretation. Actual outcrops have very irregular outlines.

0m 100 200 300 400

1 : 10000

REV	D	M	Y	ISSUE/REVISION DESCRIPTION	ENG.	APPR.
	9	9	09	ISSUED AS FINAL FOR NEB	DSC	SK
	16	6	09	ISSUED AS FINAL	DSC	SK

Client: ENBRIDGE NORTHERN GATEWAY PIPELINES

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DATUM:	NAD83
PROJECTION:	UTM Zone 9
DRAWN BY:	I.Macleod
REVIEWED BY:	S.Kelly
ORIGINAL SCALE:	1:10000

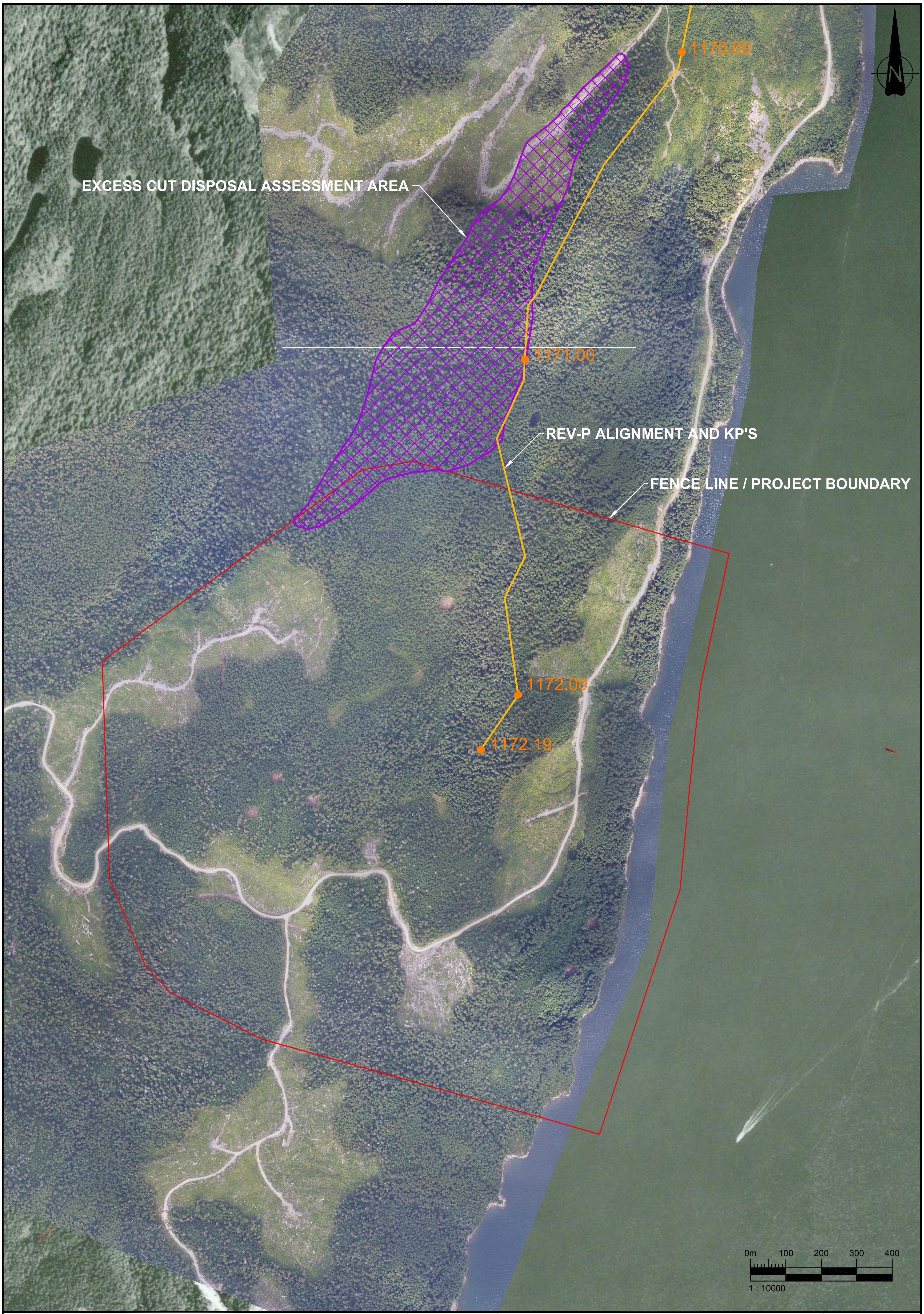
TITLE:

AERIAL PHOTO OVERVIEW AND SURFICIAL BEDROCK MAPPING

PROJECT:

PRELIMINARY GEOTECHNICAL REPORT ON PROPOSED KITIMAT TERMINAL

PROJECT NO.:	EG0926008.4200
REVISION NO.	B
DATE:	SEPTEMBER 2009
FIGURE NO.:	DRAWING 3
SHEET NO.:	1 of 1



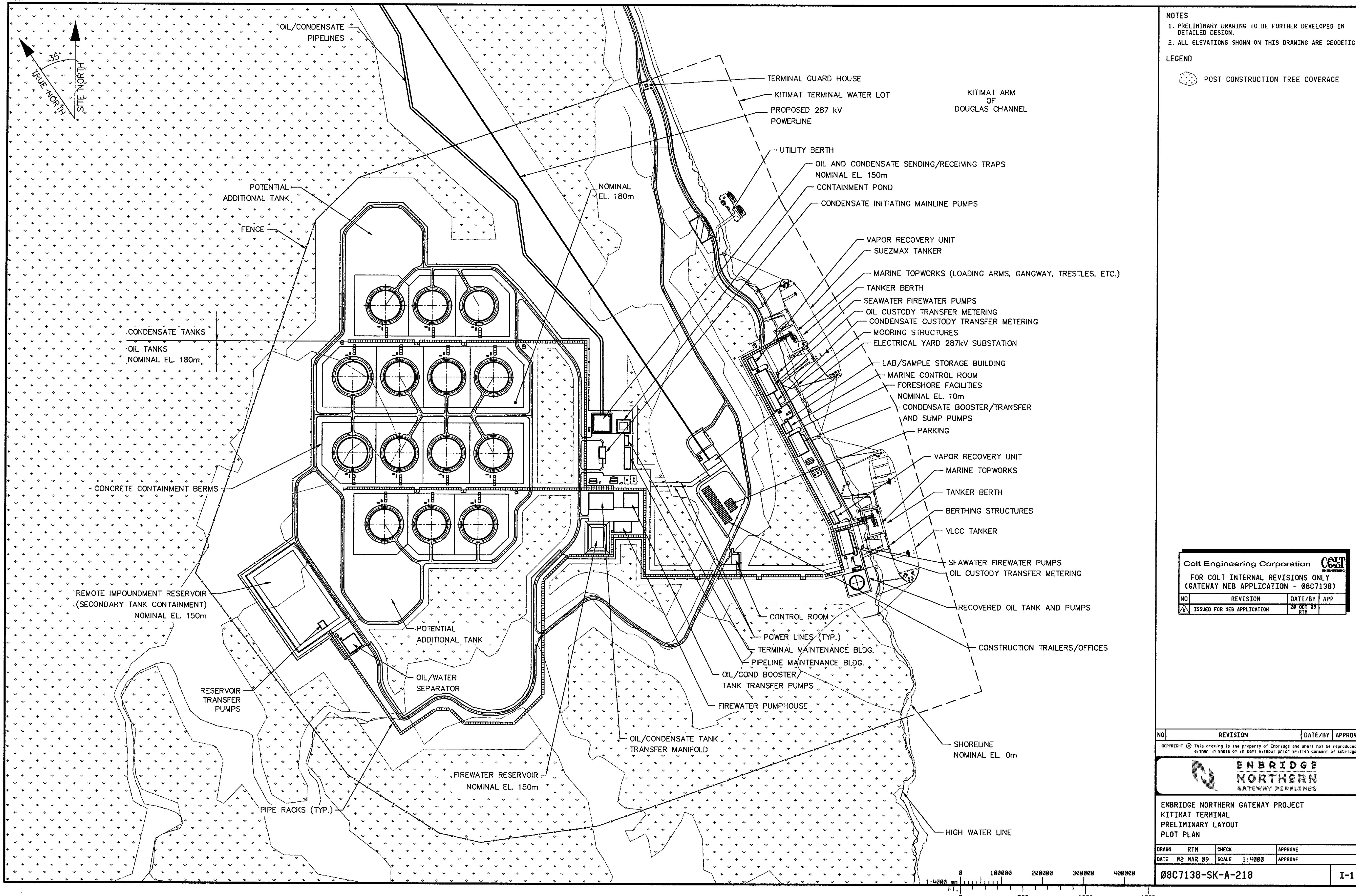
CLIENT: ENBRIDGE NORTHERN GATEWAY PIPELINES	DWN BY: I.Macleod	TITLE: EXCESS CUT DISPOSAL ASSESSMENT AREA	REV. NO.: B
	CHK'D BY: S.Kelly		DATE: SEPTEMBER 2009
AMEC Earth & Environmental 2227 Douglas Road Burnaby, BC, CANADA, V5C 5A9 Tel. (604) 294-3811 Fax (604) 294-4664 — amec	DATUM: NAD83	PROJECT: PRELIMINARY GEOTECHNICAL REPORT ON PROPOSED KITIMAT TERMINAL	PROJECT NO: EG0926008.4200
	PROJECTION: UTM Zone 9		FIGURE No. DRAWING 4
	SCALE: 1 : 10000		

S:\DRAFTING\Out Of Office - Drafting\EG09260.4220-Drafting\For DVD\EG0926008.4200-Drawing4-EXCESS.dwg - AEE-M-BP - Sep. 11, 2009 3:31pm - ian.j.macleod

This drawing was originally produced in colour.

APPENDIX A

WorleyParsons Reference Drawing



NOTES
1. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.
2. ALL ELEVATIONS SHOWN ON THIS DRAWING ARE GEODETIC.
LEGEND
POST CONSTRUCTION TREE COVERAGE
35°
TRUE NORTH
SITE NORTH
OIL/CONDENSATE PIPELINES
TERMINAL GUARD HOUSE
KITIMAT TERMINAL WATER LOT
PROPOSED 287 kV POWERLINE
KITIMAT ARM OF DOUGLAS CHANNEL
UTILITY BERTH
OIL AND CONDENSATE SENDING/RECEIVING TRAPS NOMINAL EL. 150m
CONTAINMENT POND
CONDENSATE INITIATING MAINLINE PUMPS
POTENTIAL ADDITIONAL TANK
NOMINAL EL. 180m
FENCE
VAPOR RECOVERY UNIT
SUEZMAX TANKER
MARINE TOPWORKS (LOADING ARMS, GANGWAY, TRESTLES, ETC.)
TANKER BERTH
SEAWATER FIREWATER PUMPS
OIL CUSTODY TRANSFER METERING
CONDENSATE CUSTODY TRANSFER METERING
MOORING STRUCTURES
ELECTRICAL YARD 287kV SUBSTATION
CONDENSATE TANKS
OIL TANKS NOMINAL EL. 180m
LAB/SAMPLE STORAGE BUILDING
MARINE CONTROL ROOM
FORESHORE FACILITIES NOMINAL EL. 10m
CONDENSATE BOOSTER/TRANSFER AND SUMP PUMPS
PARKING
VAPOR RECOVERY UNIT
MARINE TOPWORKS
CONCRETE CONTAINMENT BERMS
TANKER BERTH
BERTHING STRUCTURES
VLCC TANKER
SEAWATER FIREWATER PUMPS
OIL CUSTODY TRANSFER METERING
REMOTE IMPOUNDMENT RESERVOIR (SECONDARY TANK CONTAINMENT) NOMINAL EL. 150m
RECOVERED OIL TANK AND PUMPS
CONTROL ROOM
POTENTIAL ADDITIONAL TANK
POWER LINES (TYP.)
TERMINAL MAINTENANCE BLDG.
CONSTRUCTION TRAILERS/OFFICES
PIPELINE MAINTENANCE BLDG.
OIL/WATER SEPARATOR
OIL/COND BOOSTER TANK TRANSFER PUMPS
RESERVOIR TRANSFER PUMPS
FIREWATER PUMPHOUSE
OIL/CONDENSATE TANK TRANSFER MANIFOLD
SHORELINE NOMINAL EL. 0m
FIREWATER RESERVOIR NOMINAL EL. 150m
PIPE RACKS (TYP.)
HIGH WATER LINE
1:4000 mm 0 100000 200000 300000 400000
FT. 0 500 1000 1500
Colt Engineering Corporation
FOR COLT INTERNAL REVISIONS ONLY (GATEWAY NEB APPLICATION - 08C7138)
NO REVISION DATE/BY APP
A ISSUED FOR NEB APPLICATION 20 OCT 09 RTM
NO REVISION DATE/BY APPROVE
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ENBRIDGE NORTHERN GATEWAY PIPELINES
ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
PRELIMINARY LAYOUT
PLOT PLAN
DRAWN RTM CHECK APPROVE
DATE 02 MAR 09 SCALE 1:4000 APPROVE
08C7138-SK-A-218
I-1

APPENDIX B

Climate Data

Table B-1: Select Climate Information Taken from Environment Canada Data*

STATION ID	DATA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
KITIMAT 2(1)	Daily Average Temp (°C)	-2.2	0.3	3.5	7	10.8	14.3	17	17	13.1	7.9	2.4	-0.8	7.5
	Daily Maximum Temp (°C)	0.3	3	6.9	11.5	15.9	19	21.9	21.8	17.3	10.7	4.7	1.4	11.2
	Daily Minimum Temp (°C)	-4.6	-2.5	0.1	2.4	5.7	9.5	12	12.1	8.9	5	0.1	-3.1	3.8
	Extreme Maximum Temp (°C)	10.5	12	19.5	25.6	35.5	33.5	36	**36.7**	33.3	22	15.5	12.5	N/A
	Extreme Minimum Temp (°C)	-23.3	-18.9	-14.4	-7.8	-2.2	0.5	2.8	2.8	0	-12.5	-23	**-26**	N/A
	Total Monthly Rainfall (mm)	237.8	202.5	187.2	163.7	106.6	89.8	66.5	95.4	204.8	408.1	340.7	292.4	2395.5
	Total Monthly Snowfall (cm)	107.8	65.1	30	4	0	0	0	0	0	1.9	45.9	80.5	335.2
	Total Monthly Precipitation (mm)	345.6	267.6	217.2	167.6	106.6	89.8	66.5	95.4	204.8	410.1	386.6	372.5	2730.3
	Extreme Daily Rainfall (mm)	152.9	169	118.9	82	61.5	61	58.4	74.9	148	**179.4**	150	154.4	N/A
	Extreme Daily Snowfall (cm)	**82.6**	76.2	53.6	28.4	0.5	0	0	0	0	12	60	59	N/A
	Degree Days Below 0 °C	109.9	46.8	8.2	0	0	0	0	0	0	1	23.2	72.8	N/A
KITIMAT TOWNSITE(2)	Daily Average Temp (°C)	-3	-0.5	2.8	6.4	10.4	13.6	16.2	16.2	12.4	7.2	1.5	-1.5	6.8
	Daily Maximum Temp (°C)	-0.4	2.4	6.4	11.1	15.7	18.6	21.2	21.2	16.9	10.1	3.8	0.7	1.1
	Daily Minimum Temp (°C)	-5.5	-3.4	-0.8	1.7	5.1	8.7	11.2	11.2	8	4.2	-0.8	-3.7	10.6
	Extreme Maximum Temp (°C)	12.2	11.1	18	25.6	32.8	35.6	36.1	**36**	33.3	22	13.3	10	N/A
	Extreme Minimum Temp (°C)	-25	-23.9	-19.4	-10	-6.7	-0.6	3.9	2	-2	-13	-24	**-25**	N/A
	Total Monthly Rainfall (mm)	145.4	134.2	124.4	117.1	83.3	75.5	60.4	90.5	173.2	318.3	246.9	197.2	N/A
	Total Monthly Snowfall (cm)	138.5	77.5	42.9	6.2	0.1	0	0	0	0	2.8	53.3	102.6	1766.7
	Total Monthly Precipitation (mm)	284	211.7	167.4	123.3	83.4	75.5	60.4	90.5	173.2	321.1	300.2	299.9	423.9
	Extreme Daily Rainfall (mm)	95.8	86.6	108	71.6	57.2	46.6	49	57.4	130	**144.8**	110	129.4	N/A
	Extreme Daily Snowfall (cm)	**106.9**	112.3	58.4	28.2	1	0	0	0	0	33	78.7	57.2	N/A
	Degree Days Below 0 °C	121.8	53.9	11.6	0	0	0	0	0	0	1.3	28.8	79.8	N/A

Notes

1. KITIMAT 2, location from Environment Canada: 54°00'N, 128°42'W, 17m elev
2. KITIMAT TOWNSITE, location from Environment Canada: 54°03'N, 128°38'W, 128m elev

Figure B-1
Monthly Rainfall

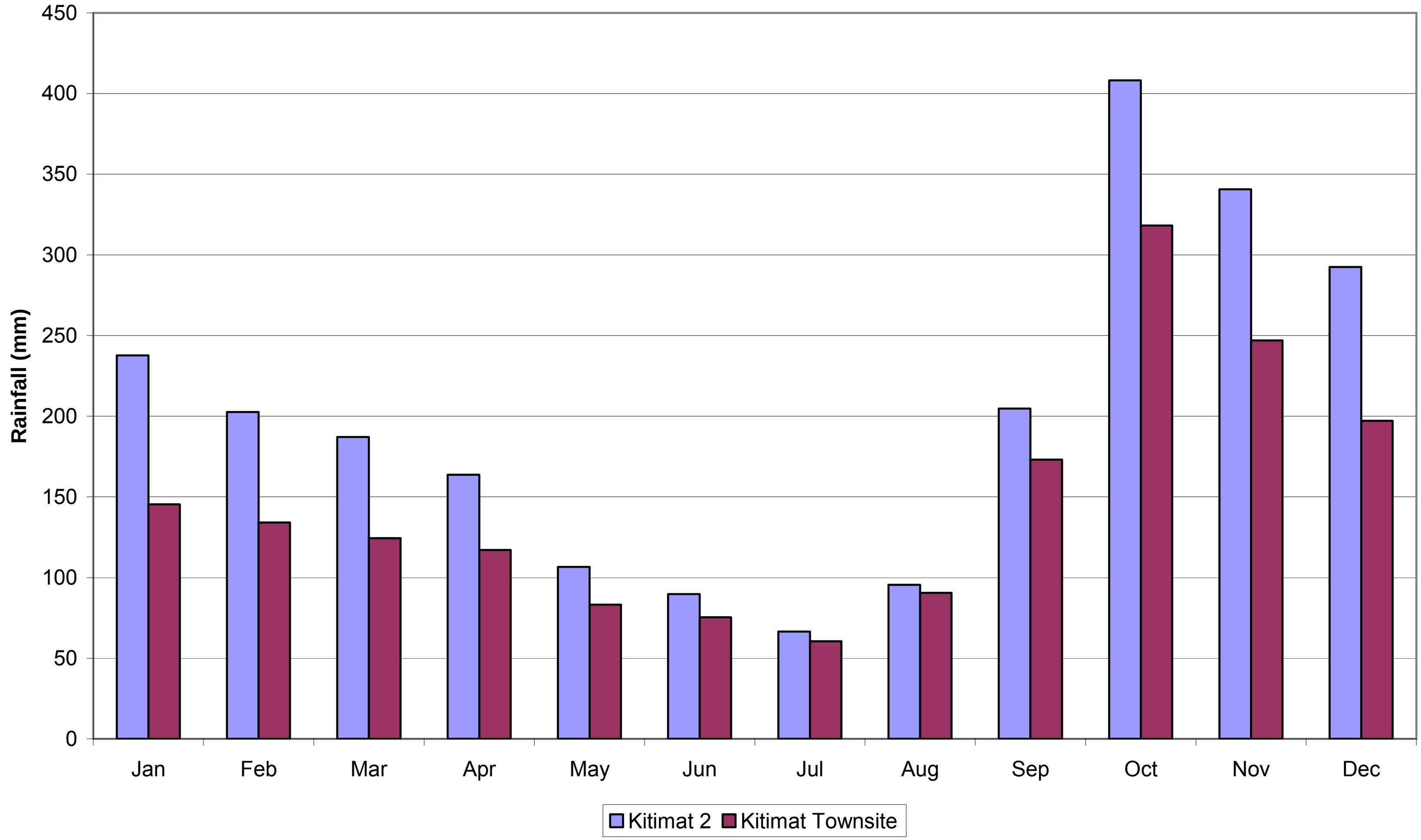


Figure B-2
Monthly Snowfall

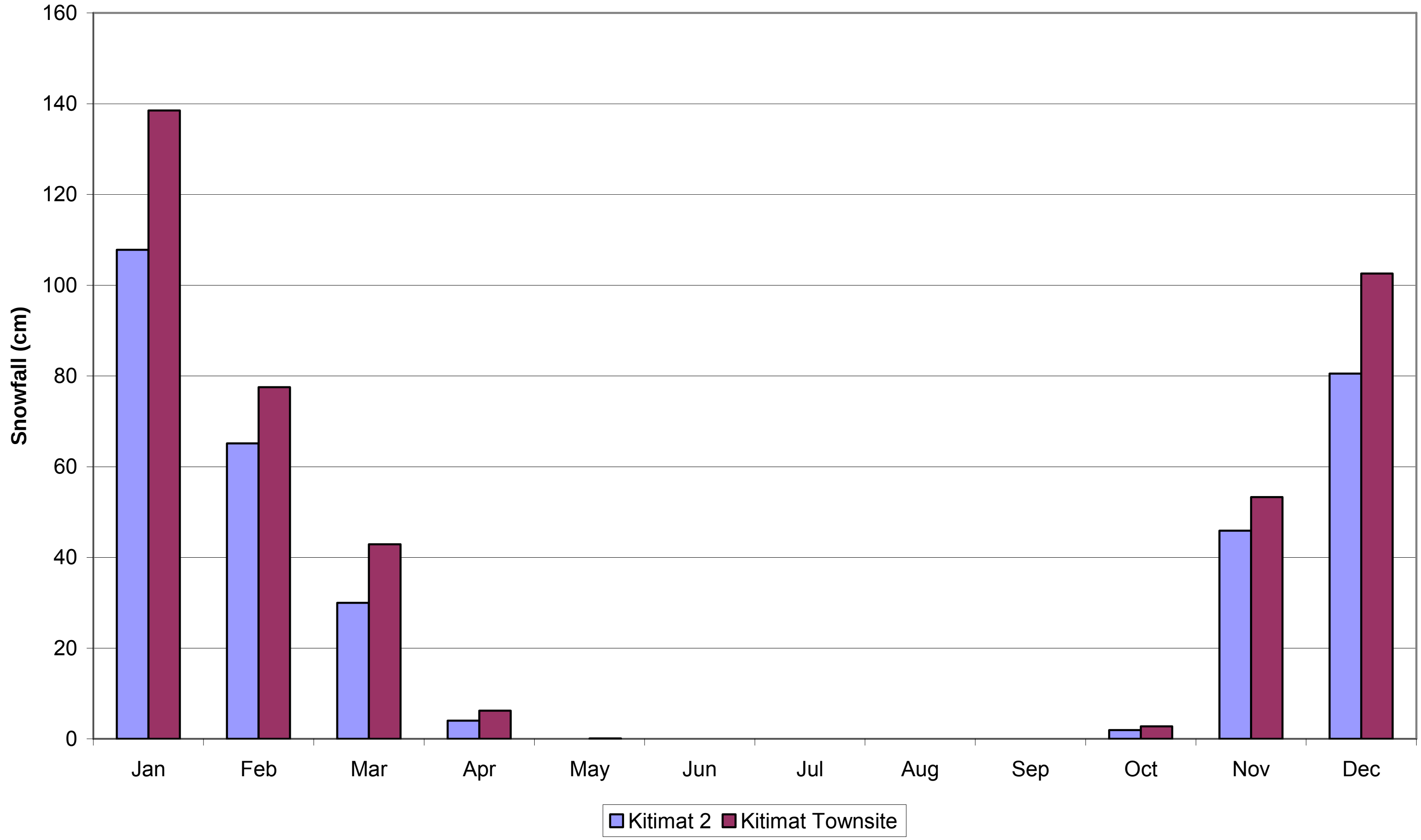
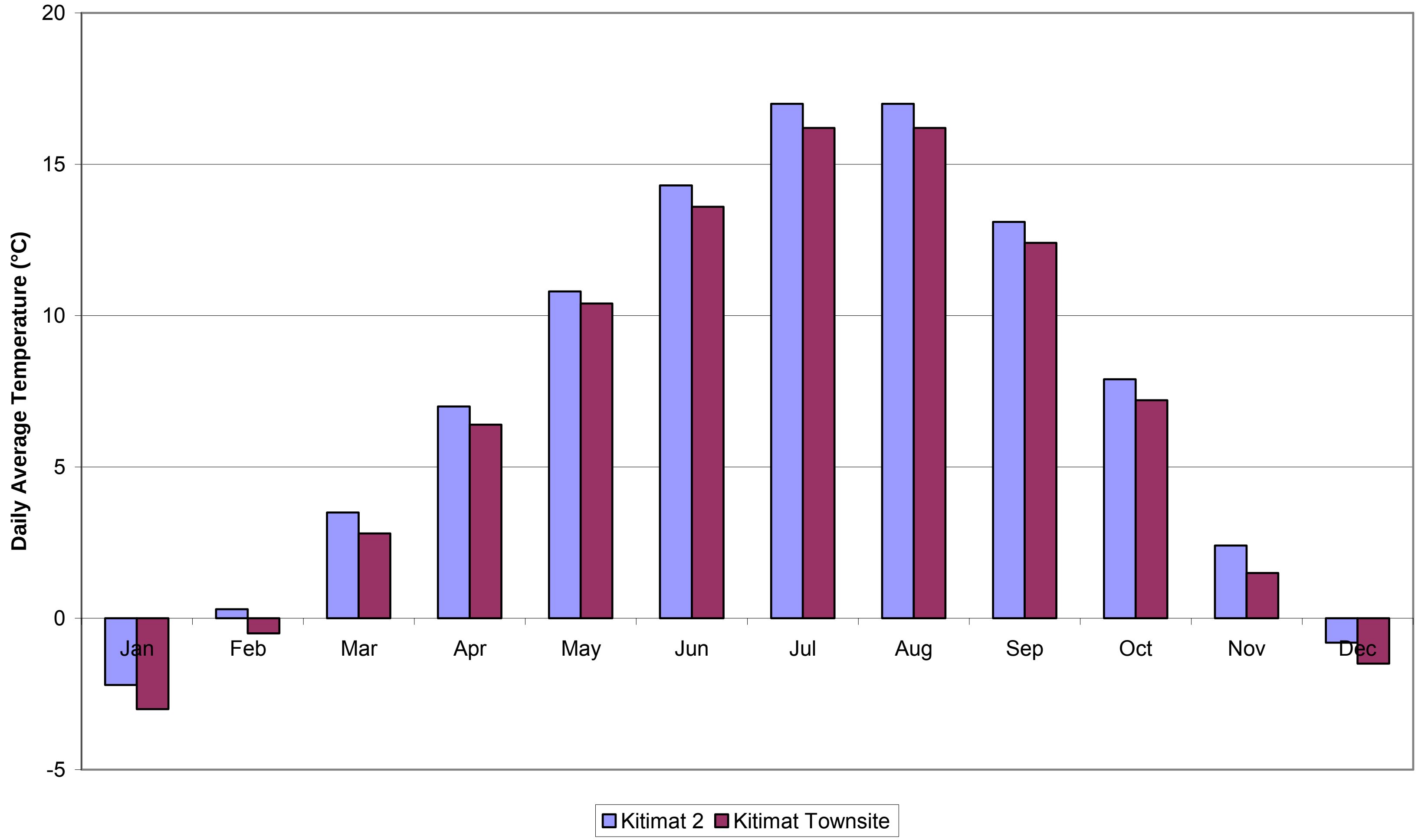


Figure B-3
Daily Average Temperature



APPENDIX C

Surficial Bedrock Mapping Traverse Notes and Measurements

TABLE C-1 – OUTCROP MAPPING TRAVERSE NOTES

AMEC TRAVERSE #06-01							
Date:	**October 18, 2006**						
Weather:	**Overcast, becoming partly clouded late in the day**						
Station	**Northing**	**Easting**	**Elevation**	**Foliation Measurement**	**Sample**	**Photo**	**Comments**
A1	5977217	518326	-	280/68 NE	$A1_a$ $A1_1$ $A1_2$	101_0869	We are in a quartz rich gneiss (Sample $A1_a$) cut by 10 m wide felsic dyke trending 070. Photo of dyke with an inclusion of gneiss.
A1a	5977195	518301	143	296/65 NE		101_0870 101_0871	At 7 km marker, we are in a gneiss with quartz veining.
A1b	5977177	518279	-	185/25-65		101_0872	We are in a gneiss with quartz and plagioclase veining running perpendicular and parallel to the foliation. The gneiss is cut by a 4 m wide oxidized quartz diorite dyke at 012/60 SE. The contact of the dyke and gneiss is badly broken on the south side. Nearby float contains sulfides.
A1c	5977420	518126	147			101_0873	We are in a gneiss with quartz and plagioclase veins and quartz augens. Striated at 080 with chlorite alteration. Medium-coarse-grained quartz diorite dyke at 345/55 NE, 20-40 cm thick. Photo of dyke and striated joint surface.
A1d	5977308	517943	-			101_0874	We are in a strongly banded gneiss containing augens, becoming schistose in parts. The bands are 1-3 cm.

AMEC TRAVERSE #06-01 (continued)							
DATE:	**OCTOBER 19, 2006**						
WEATHER:	**OVERCAST AND PARTLY CLOUDED**						
STATION	**NORTHING**	**EASTING**	**ELEVATION**	**FOLIATION MEASUREMENT**	**SAMPLE**	**PHOTO**	**COMMENTS**
A2	5977826	518740	85			101_0875 to 101_0894	We are in gneiss and schist with felsic dykes. The schists are the dominant metamorphic rock (chlorite & green minerals) containing 1-2% disseminated sulfides and up to 5% on joint surfaces. Felsic dykes 246/43 E, 025/61 SE (30 cm wide), 080/65 SE (30 cm wide), 060/50 SE (30 cm wide), 070/30 SE (1.5 m wide), 070/55 SE (10 cm wide). Quartz diorite dyke 330/66 (1 m wide).
A2a	5977733	518674	94				We are in a quartz rich schist with ~ 10% mafics. Float from a medium grained felsic dyke downhill. Granitic dyke at 310/55 NE (50 cm wide), containing dioritic inclusions.
A2b	5977771	518634	135		A2b		We are in a greenish schist.
A2c	5977858	518413	170				No outcrop.

AMEC TRAVERSE #06-01 (continued)							
DATE:	**OCTOBER 19, 2006**						
WEATHER:	**OVERCAST AND PARTLY CLOUDED**						
STATION	**NORTHING**	**EASTING**	**ELEVATION**	**FOLIATION MEASUREMENT**	**SAMPLE**	**PHOTO**	**COMMENTS**
A2d	5977812	518561	150				We are in a gneiss/schist, with a granitic dyke containing 5-10% mafics.
A2e	5977877	518422	171				We are in a gneiss/schist with a felsic dyke 315/70 NE (15 cm wide)
A2f	5977672	518783	-				We are in a quartz gneiss, containing 1% disseminated sulfides.
A2g	5977633	518815	83				We are in a gneiss/schist with a felsic dyke 165/28 SW (2-3 m wide)
A2h	5977568	518807	48				We may be in a granodiorite dyke 20 m wide, some schist float.
A2i	5977481	518765	102	295/53 NE 265/28 NW		101_0910 101_0911	We are in a gneiss with a felsic dyke.
A2j	5977423	518783	66	285/67 NE			We are in quartz augen gneiss.
A2k	5977350	518767	62				We are in gneiss.
A2l	5977160	518643	90				No outcrop.
A2m	5977004	517995	153	272/64 NE			We are in quartz gneiss.

AMEC TRAVERSE #06-01 (continued)							
DATE:	**OCTOBER 19, 2006**						
WEATHER:	**OVERCAST AND PARTLY CLOUDED**						
STATION	**NORTHING**	**EASTING**	**ELEVATION**	**FOLIATION MEASUREMENT**	**SAMPLE**	**PHOTO**	**COMMENTS**
A2n	5976989	518159	151				Felsic dyke (>3 m wide)
A3	5977203	518029	164				No outcrop, very little outcrop seen between 303 & 305 lines in and around the ravine.
A3a	5977237	517936	157				No outcrop between **A3 & A3a**.
A3b	5976650	517903	143	250/43 NW	$A3B_1$ $A3B_2$		We are in strongly foliated quartz diorite, partially recrystallized. Grain size varies in 10-20 cm bands from coarse to medium. Fine to medium grained unfoliated granodiorite dykes parallel to foliation. Contains K-feldspar and quartz megacrysts. Samples taken from 5 m wide granite dyke containing inclusions of foliated quartz diorite.
A3c	5976454	517911	117	285/23 NE	A3c		We are in moderately foliated quartz diorite, medium grained cut by unfoliated granodiorite dykes.

AMEC TRAVERSE #06-01 (continued)							
DATE:	**OCTOBER 19, 2006**						
WEATHER:	**OVERCAST AND PARTLY CLOUDED**						
STATION	**NORTHING**	**EASTING**	**ELEVATION**	**FOLIATION MEASUREMENT**	**SAMPLE**	**PHOTO**	**COMMENTS**
A3d	5976924	517879	150	130/50 NE (in Quartz Diorite)			We are at the contact between a strongly foliated quartz diorite and quartz gneiss.
A3e	5976942	517897	152	120/51 NE (in Gneiss)			We are at the gradational contact between the gneiss and quart diorite, which follows the foliation.
A3f	5977499	517268	122	090/35 N to 305/53 NE		101_0925 to 1-1_0940	We are in gneiss cut by foliated quartz diorite dykes (305/53 NE), unfoliated quartz diorite dykes (070/47), and unfoliated felsic dykes (295/54 NE) to (080/15 E). 1-2% sulphides in gneiss.
A3g	5977938	517437	146	165/90 (in Gneiss)	A3g		We are in granodiorite, containing apophyses of foliated quartz diorite and gneiss.
A3h	5977931	517549	167				At CP 10. We are in unfoliated quartz diorite intruded by felsic dyke (091/59 SW), granitic dyke 2 m wide (206/52 NE)
A3i	5978023	517655	152	140/75 SW			Foliated quartz diorite, contains inclusions of gneiss.

AMEC TRAVERSE #06-01 (continued)							
DATE:	**OCTOBER 19, 2006**						
WEATHER:	**OVERCAST AND PARTLY CLOUDED**						
STATION	**NORTHING**	**EASTING**	**ELEVATION**	**FOLIATION MEASUREMENT**	**SAMPLE**	**PHOTO**	**COMMENTS**
A3j	5978123	517818	167				At CP 11. We are in unfoliated quartz diorite-granodiorite containing an apophysis of gneiss.
A3k	5977974	517737	168				We are in quartz diorite.
A3l	5977791	517917	203				We are in gneiss with quartz diorite and a felsic dyke (striking 050).
A3m	5977744	517973	215		A3m		We are in quartz gneiss.
A3n	5977690	518030	90				137 & 111 lines intersection. No outcrop.
A3o	5977793	518060	190				133 & 111 lines intersection. No outcrop.
A3p	5977848	518028	188				We are in a felsic dyke.
A3q	5977917	517940	202				105 & 133 lines intersection. No outcrop.
A3r	5977848	517878	194				105 & 137 lines intersection. No outcrop.

Table C-2 – OUTCROP MAPPING STRUCTURAL MEASUREMENT DETAILS

Station/Point	Easting (m)	Northing (m)	Elev. (m)	Structure	Strike*/Trend	Dip*/ Plunge	Quad	Persistence (m)	J spacing F&D thick (m)		Alteration	Infill	Aperture (mm)	Macro (Nature)	Micro (Nature)	Comments	Photo	Rock Mass Rating (1989)					
									Min	Max								P1	P2	P3	P4	P5	RMR Total
A1	518326	5977217		Foliation	280	68	NE																
A1	518326	5977217		Jsw	265	60	NW	>8	0.2	0.3	none	none	0	planar	smooth								
A1	518326	5977217		J	347	90		2	0.1	1.0	none	none	0	planar	rough								
A1	518326	5977217		Jsw	215	45	NW	2	0.2		possible	none	0	planar	rough								
A1	518326	5977217		Jse	100	79	SW	>2	0.5		none	none	0	planar	rough	RQD 50%, 2-3 blows to break	101_0867-68	10	10	9	24	10	63
A1	518326	5977217		Jne	010	75	SE	>1	0.6		none	none	0	planar	rough	continues through contact, RQD 10-50%, 1 blow. Material on right of photo 101_0868		4	6	10	25	10	55
A1a	518301	5977195	143	Foliation	296	65	NE										101_0870-71						
A1b	518279	5977177		Jnw	351	66	NE	>5	1.0		none	none	0	planar	rough								
A1b	518279	5977177		Jse	135	50	SW	>2	0.3	1.0	none	none	0	planar	rough								
A1b	518279	5977177		Jnw	275	55	NE	>5	1.0	3.0	none	none	0	planar	rough	continues through dyke							
A1b	518279	5977177		Foliation	285	25-65	NE									RQD >80%, >4-5 blows to break	101_0872	14	16	13	25	10	78
A1c	518126	5977420	147	Jne	058	49	SE	>2	1.0		chlorite	none	2	planar	smooth	striated at 80º							
A1c	518126	5977420	147	Jnw	340	70	NE	>6	0.3	0.5	none	none	0	planar	rough								
A1c	518126	5977420	147	Jsw	185	43	NW	3	0.3	0.5	chlorite	none	0	planar	rough	RQD 30%, 2-4 blows	101_0873	11	6	12	10	10	49
A1d	517943	5977308		Jsw	240	65	NW	1	0.3		none	none	0	planar	rough								
A1d	517943	5977308		Jnw	335	70	NE	>1	0.4		none	none	0	planar	rough	RQD 70%, 3-4 blows to break	101_0874	13	14	10	25	10	72
A2	518740	5977826	85	Jne	007	57	SE	>8	0.3		none	none	0	planar	rough								
A2	518740	5977826	85	Jsw	203	60	NW	>7	0.5		none	none	0	planar	rough								
A2	518740	5977826	85	Jse	150	50	SW	>10	0.2	0.5	chlorite	none	0	planar	rough								

Station/Point	Easting (m)	Northing (m)	Elev. (m)	Structure	Strike*/Trend	Dip*/ Plunge	Quad	Persistence (m)	J spacing F&D thick (m)		Alteration	Infill	Aperture (mm)	Macro (Nature)	Micro (Nature)	Comments	Photo	Rock Mass Rating (1989)					
									Min	Max								P1	P2	P3	P4	P5	RMR Total
A2	518740	5977826	85	Jne	030	50	SE	>8	0.6	1.0	chlorite	none	0	planar	rough	RQD 30-80%, >5 blows	101_0875-98 (minus 94)						
A2	518740	5977826	85	Jnw	320	48	NE	>10	0.3		none	none	0	planar	rough	at south end of outcrop							
A2	518740	5977826	85	J	000	90		>10	0.3	0.5	iron oxide	none	0	planar	rough	at south end of outcrop							
A2	518740	5977826	85	Jse	130	60	SW	>6	0.2	1.0	none	none	0	planar	rough	at south end of outcrop	101_0896-98 for south end	15	11	12	12	10	60
A2a	518674	5977733	94	Jsw	205	76	NW	>1.5	0.6		none	none	0	planar	rough								
A2a	518674	5977733	94	Jse	110	70	SW	>1	0.4		none	none	0	planar	rough	RQD 70%, 3-4 blows to break	101_0901	13	14	11	25	10	73
A2b	518634	5977771	135	Jne	057	81	SE	>3			none	sand	1-2	planar	rough								
A2b	518634	5977771	135	Jne	020	85	SE	>1	0.3		?	none	1-2	planar	rough	RQD 10-20%, 1 blow to break	101_0902	4	3	9	10	10	36
A2d	518561	5977812	150	Jse	095	56	SE	>0.8	0.3		none	sand	1	planar	rough								
A2d	518561	5977812	150	Jne	040	75	SE	>2			none	?		planar	rough								
A2d	518561	5977812	150	Jsw	225	20	NW	>2	0.2		none	none	0	planar	rough	RQD 40%, 4 blows to break	101_0903	14	8	9	10	10	51
A2e	518422	5977877	171	Jsw	210	73	NW	>2	0.4		none	none	2-3	planar	rough								
A2e	518422	5977877	171	Jnw	310	70	NE	>1	0.2		none	none	0	planar	rough	RQD 20-40%, 4 blows to break	101_0905	14	6	10	10	10	50
A2f	518783	5977672		Jne	020	86	SE	>2	2.0	1.0	none	silt	1	planar	rough								
A2f	518783	5977672		Jnw	320	64	NE	>2	0.1	0.5	none	none	0	planar	rough								
A2f	518783	5977672		Js	180	52	W	>2	0.3		none	none	0	planar	rough	RQD 50-60%, 3-4 blows to break	101_0906	13	11	10	10	10	54
A2g	518815	5977633	83	Jne	012	55	SE	>5	0.9		none	none	0	planar	rough								
A2g	518815	5977633	83	Jne	062	77	SE	1.5	0.2	0.5	none	none	0	planar	rough								
A2g	518815	5977633	83	Jsw	200	30	NW	>3	0.8		none	none	0	planar	rough	RQD 80%, 3-4 blows	101_0907	13	16	14	25	10	78
A2h	518807	5977568	48	Jne	036	60	SE	>3	0.3		none	none	0	planar	rough								
A2h	518807	5977568	48	Jse	175	38	SW	2	0.4		none	none	2	planar	rough								

Station/Point	Easting (m)	Northing (m)	Elev. (m)	Structure	Strike*/Trend	Dip*/ Plunge	Quad	Persistence (m)	J spacing F&D thick (m)		Alteration	Infill	Aperture (mm)	Macro (Nature)	Micro (Nature)	Comments	Photo	Rock Mass Rating (1989)					
									Min	Max								P1	P2	P3	P4	P5	RMR Total
A2h	518807	5977568	48	Jne	070	87	SE	>1	0.2	0.3	none	quartz	0	planar	rough	filled with a quartz vein, RQD 80%, 3-4 blows	101_0908	13	16	10	10	10	59
A2i	518765	5977481	102	Foliation	295	53	NE										101_0910						
A2i	518765	5977481	102	Foliation	265	28	NW										101_0911						
A2i	518765	5977481	102	Jne	010	52	SE	>5	0.2		none	none	0	planar	rough								
A2i	518765	5977481	102	Jsw	185	63	NW	0.8	0.1		none	none	0	planar	rough								
A2i	518765	5977481	102	Jsw	250	60	NW	>2	0.5		none	none	0	planar	rough								
A2i	518765	5977481	102	Jne	040	50	SE	1.2	1.5		none	none	0	planar	rough	RQD 30-60%, 2-4 blows	101_0909	11	9	8	25	10	63
A2j	518783	5977423	66	Foliation	285	67	NE																
A2j	518783	5977423	66	Jne	089	64	SE	>2	2.0		none	none	0	planar	rough								
A2j	518783	5977423	66	J	053	90		2	0.1	0.3	none	none	0	planar	rough								
A2j	518783	5977423	66	Jnw	280	65	NE	>1	0.1		none	none	0	planar	smooth	RQD 60%, >4 blows	101_0912	14	12	8	24	10	68
A2k	518767	5977350	62	Jnw	320	35	NE	>1	0.1	0.20	none	none	1	planar	rough								
A2k	518767	5977350	62	Jne	010	60	SE	>1	0.2		none	none	0	planar	rough	RQD 40%, 3-4 blows	101_0913	13	8	8	15	10	54
A2m	517995	5977004	153	Foliation	272	64	NE																
A2m	517995	5977004	153	Jsw	220	45	NW	>0.5	0.4		none	none	0	planar	rough								
A2m	517995	5977004	153	Je	090	65	S	>0.4			none	none	0	planar	rough								
A2m	517995	5977004	153	Jnw	340	35	NE	>0.5			none	none	0	planar	rough	RQD 0-10%, >4 blows	101_0914	14	5	10	25	10	64
A2n	518059	5976989	151	Jsw	252	60	NW	>1	0.2	0.3	none	none	0	planar	rough								
A2n	518059	5976989	151	Jse	155	62	SW	>1	0.1	0.5	none	none	0	planar	rough	RQD 10-20%, 2-4 blows	101_0915	11	3	10	25	10	59
A3b	517903	5976650	143	Jnw	353	68	NE	>5	0.5	1.0	none	none	0	planar	rough								
A3b	517903	5976650	143	Jsw	255	31	NW	>3	0.5		none	none	0	planar	rough								
A3b	517903	5976650	143	Jsw	228	35	NW	>6	0.25		none	sand	1	planar	smooth								
A3b	517903	5976650	143	Jsw	215	67	NW	>3	0.2	1.0	none	none	2-3	planar	smooth								
A3b	517903	5976650	143	Jne	075	59	SE	1.5	0.5		none	none	0	planar	rough								
A3b	517903	5976650	143	Foliation	250	43	NW									RQD 80-90%, 3-4+ blows	101_0916-101_0918	13	17	13	10	10	63

Station/Point	Easting (m)	Northing (m)	Elev. (m)	Structure	Strike*/Trend	Dip*/ Plunge	Quad	Persistence (m)	J spacing F&D thick (m)		Alteration	Infill	Aperture (mm)	Macro (Nature)	Micro (Nature)	Comments	Photo	Rock Mass Rating (1989)					
									Min	Max								P1	P2	P3	P4	P5	RMR Total
A3c	517911	5976454	117	Foliation	285	23	NE																
A3c	517911	5976454	117	Jsw	210	76	NW	>1	0.3		chlorite	none	0	planar	smooth								
A3c	517911	5976454	117	Jne	005	35	SE	1	0.6		none	none	0	planar	rough								
A3c	517911	5976454	117	J	180	90		>0.6	0.4		none	none	0	planar	rough	RQD 40%, >4 blows	101_0921-101_0922	14	8	11	15	10	58
A3d	517879	5976924	156	Foliation	310	50	NE																
A3d	517879	5976924	156	Jsw	195	38	NW	>5	0.8		none	none	0	planar	smooth								
A3d	517879	5976924	156	Jsw	184	76	NW	>3	0.4		none	none	0	planar	smooth								
A3d	517879	5976924	156	Jne	040	69	SE	>10	1.25		none	none	0	planar	smooth	RQD 80-90%, >4 blows	101_0923	14	17	13	20	10	74
A3e	517897	5976942	152	Foliation	300	51	NE										101_0924						
A3f	517268	5977499	122	Foliation	305	53	NE																
A3f	517268	5977499	122	Foliation	295	54	NE																
A3f	517268	5977499	122	J	195	90		15	0.4		none	none	1	planar	rough								
A3f	517268	5977499	122	Jnw	300	46	NE	>20	0.2		none	none	0	planar	rough								
A3f	517268	5977499	122	Jse	151	61	SW	>15	0.2	1.0	none	none	0	planar	smooth								
A3f	517268	5977499	122	J	205	0		>5	1.25		none	none	0	undulating	rough	RQD 85%	101_0925-101_0940	14	17	10	15	10	66
A3g	517437	5977938	146	Foliation	165	90																	
A3g	517437	5977938	146	Jse	165	75	SW	>2	0.4		none	none	5	planar	smooth								
A3g	517437	5977938	146	Jne	060	10	SE	>2	0.75		none	none	5	planar	rough								
A3g	517437	5977938	146	Jsw	256	75	NW	>2			none	none	0	planar	smooth								
A3g	517437	5977938	146	Jne	040	85	SE	>3	0.3		none	none	0	planar	smooth	RQD 75%, >4 blows	101_0941	14	15	11	1	10	51
A3h	517549	5977931	167	Jsw	260	75	NW	>5	0.3		none	none	0	planar	smooth								
A3h	517437	5977938	167	Jne	023	46	SE	>20	0.3		none	none	0	planar	rough								
A3h	517437	5977938	167	Jse	174	58	SW	>20	0.2		none	none	1-2	planar	rough	RQD 10%, >4 blows	101_0942	14	2	10	10	10	46
A3i	517655	5978023	152	Foliation	140	75	SW																
A3i	517655	5978023	152	Jsw	240	61	NW	>0.5			none	none	0	planar	rough								
A3i	517655	5978023	152	J	171	90		>0.15	0.4	0.5	none	none	0	planar	rough	RQD 70%, >4 blows	101_0943	14	14	11	25	10	74
A3j	517818	5978123	167	Jne	035	80	SE	>6	0.2		none	none	0	planar	rough								
A3j	517818	5978123	167	Jse	150	66	SW	>2	0.2	0.5	none	none	0	planar	rough								

Station/Point	Easting (m)	Northing (m)	Elev. (m)	Structure	Strike*/Trend	Dip*/ Plunge	Quad	Persistence (m)	J spacing F&D thick (m)		Alteration	Infill	Aperture (mm)	Macro (Nature)	Micro (Nature)	Comments	Photo	Rock Mass Rating (1989)					
									Min	Max								P1	P2	P3	P4	P5	RMR Total
A3j	517818	5978123	167	Jnw	315	33	NE	.2	1.0		none	none	0	planar	rough								
A3j	517818	5978123	167	Jsw	223	32	NW	1	0.1	2.0	none	none	0	planar	rough	RQD 70-80%, 3-4 blows	101_0944	13	15	11	25	10	74
A3l	517917	5977791	203	Jnw	275	57	NE	>2	0.5		none	none	0	planar	rough								
A3l	517917	5977791	203	Jsw	197	80	NW	>2	0.15		none	none	1	planar	rough								
A3l	517917	5977791	203	Jne	079	15	SE	0.3	0.3		none	none	0	planar	rough	RQD 40%, >4 blows	101_0945	14	8	9	15	10	56
A3m	517973	5977744	215	Jsw	250	55	NW	>0.4	1.0		none	none	0	planar	rough								
A3m	517973	5977744	215	Jsw	205	65	NW	>3	0.3		none	none	0	planar	rough								
A3m	517973	5977744	215	Jne	078	75	SE	>0.5	0.8		none	none	0	planar	rough	RQD 50%, 3 blows	101_0946	13	10	13	25	10	71
A3p	518028	5977848	188	Jnw	280	74	NE	>0.2			none	none	0	planar	rough								
A3p	518028	5977848	188	Jse	172	80	SW	>0.4			none	none	0	planar	rough	RQD 90%, >4 blows		14	18	10	25	10	77

APPENDIX D

Drill Hole Logs, Test Pit Logs, Rock Core Photos, CPT and VST Data

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-01**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: M5T/Hollow Stem Auger/ODEX	NORTHING: 5977281.7 EASTING: 517378.7	ELEVATION: 99.6 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m) | GASTECH READINGS (PPM) 200 400 600 800 | PLASTIC M.C. LIQUID 20 40 60 80 | SOIL SYMBOL | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE NO | RECOVERY (%) | ADDITIONAL INFORMATION | ELEVATION (m)

SOIL DESCRIPTION	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION
ORGANICS, some wood, roots, peat, wet, brown			
CLAY, some silt, some fine grained sand, some rootlets, intermediate plastic, stiff, brown, moist, fissured at 0.58m with some small sub-rounded stones (<7mm diameter)	1	100	sample taken with Enviro spoon
	2	100	
-some fine grained sand, mottled -trace gravel	3	100	sample taken with Enviro spoon Atterberg: Non-plastic
SAND, clayey, some gravel, compact, moist to wet, brown -1" wet pocket	4	50	refusal with Shelby Tube
-some coarse sand and fine grained gravel, compact	5 6		refusal with 3" Enviro spoon, no sample taken (not enough sample in spoon) switched to open hole mud rotary drilling
	7		
-light to dark grey chips and cuttings, 100% fractures	8		
- very fine silty sand, some rock chips, mostly sub-rounded small stones (No. 50), dark grey, logged from cuttings	9		
- very fine silty sand, dark grey, logged from cuttings	10		
BEDROCK	11		
	12		
	13		
	14		
End of Hole at 11.9 m			

Depth (m): 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

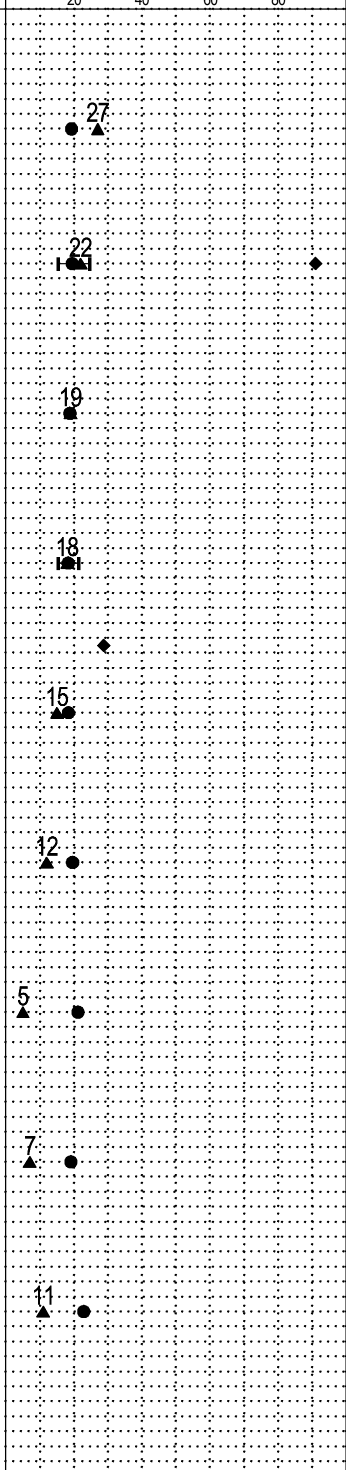
Elevation (m): 99 98 97 96 95 94 93 92 91 90 89 88 87 86 85

AMEC Earth & Environmental 2227 Douglas Road Burnaby, British Columbia CANADA, V5C 5A9	LOGGED BY: GM ENTERED BY: BP	COMPLETION DEPTH: 11.9 m COMPLETION DATE: 7/16/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-03**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: M5T/Hollow Stem Auger/ODEX	NORTHING: 5977347.5 EASTING: 517664.1	ELEVATION: 137.4 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m) | ▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 | ◆ POCKET PEN (kPa) ◆ 100 200 300 400 | PLASTIC M.C. LIQUID 20 40 60 80 | SOIL SYMBOL | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE NO | RECOVERY (%) | ADDITIONAL INFORMATION | ELEVATION (m)



SOIL DESCRIPTION

ORGANICS, wood debris, reddish

SAND and GRAVEL, some silty clay, angular rock fragments, brown to grey, dry to moist

CLAY, silty, trace sand, trace gravel, trace organics, low plasticity, stiff to very stiff, light to dark grey, moist. Intermittent sand, silt and clay layers.

-increasing silt content

SILT, some fine sand to sandy, some clay, trace gravel, low plasticity to non-plastic, stiff to very stiff, moist to wet

- intermittent sand, silt and clay layers

SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION
1	47	Enviro spoon sample
2	94	
3	77	Enviro spoon sample
5	88	Grain Size analysis Sand: 5% Silt: 63% Clay: 32%
6	73	Enviro spoon sample
7	80	
8	73	Enviro spoon sample
9	83	Grain Size Analysis Sand: 10% Silt: 66% Clay: 24%
10	77	Enviro spoon sample
11	71	
12	77	Enviro spoon sample
13	96	Grain Size Analysis Sand: 19% Silt: 63% Clay: 18% Atterberg: Non-plastic
14	79	Grain Size Analysis Sand: 22% Silt: 55% Clay: 23%
15	100	increasing water content (possibly from drilling) Spoon sunk 88mm under own weight
16	100	
17	100	Shelby Tube sunk 38mm under own weight

DEPTH (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

ELEVATION (m): 137, 136, 135, 134, 133, 132, 131, 130, 129, 128, 127, 126, 125, 124, 123

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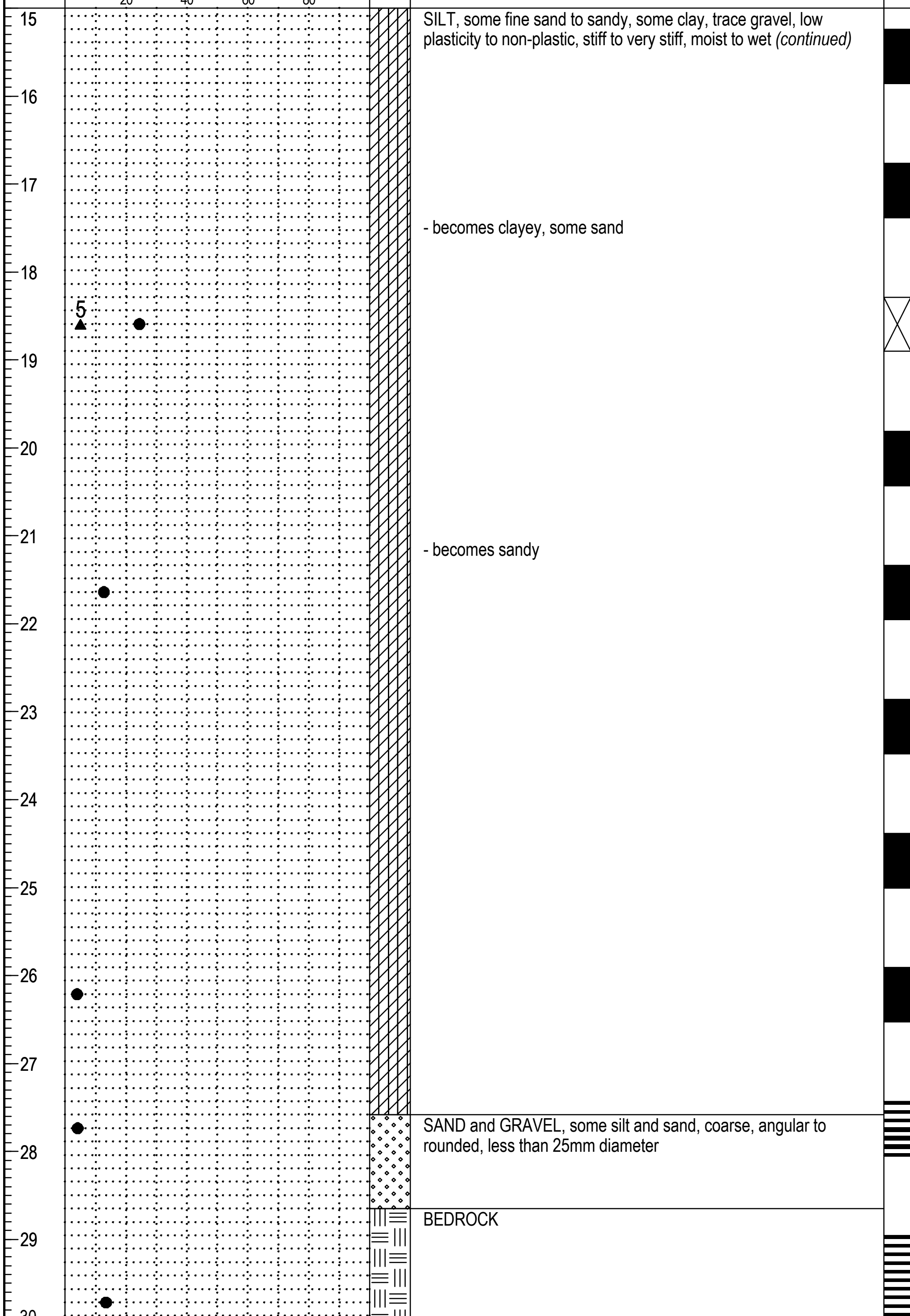
AMEC Earth & Environmental
2227 Douglas Road
Burnaby, British Columbia
CANADA, V5C 5A9

LOGGED BY: DL/GM	COMPLETION DEPTH: 33.2 m
ENTERED BY: BP	COMPLETION DATE: 7/12/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-03**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: M5T/Hollow Stem Auger/ODEX	NORTHING: 5977347.5 EASTING: 517664.1	ELEVATION: 137.4 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80; ◆ POCKET PEN (kPa) ◆ 100 200 300 400; PLASTIC M.C. LIQUID 20 40 60 80



DEPTH (m)	SOIL DESCRIPTION	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
15	SILT, some fine sand to sandy, some clay, trace gravel, low plasticity to non-plastic, stiff to very stiff, moist to wet *(continued)*	18	100		122
17	- becomes clayey, some sand	19		Shelby Tube sunk 102mm under own weight	120
18.5		20		Grain Size Analysis Sand: 15% Silt: 66% Clay: 19%	119
20		21	100	Shelby Tube sunk 76mm under own weight	117
21	- becomes sandy	22	0	Shelby Tube sunk 470mm under own weight	116
23		23	100	Shelby Tube sunk 90mm under own weight	114
24.5		24	100	Shelby Tube sunk 102mm under own weight	113
26		25	0	Shelby Tube sunk 102mm under own weight switched to open hole drilling	111
27.5	SAND and GRAVEL, some silt and sand, coarse, angular to rounded, less than 25mm diameter	26 29 27 28		switching to hollow stem auger gravel sloughing	110
28.6	BEDROCK	30		switched to open hole drilling switched to hollow stem auger switched to open hole drilling noticed smell from clay	109
30		31			108

BOREHOLE LOG EG09260-4220-DH-GATEWAY.GPJ AMEC PG.GDT 5/19/09

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CANADA, V5C 5A9

LOGGED BY: DL/GM	COMPLETION DEPTH: 33.2 m
ENTERED BY: BP	COMPLETION DATE: 7/12/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-03**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: M5T/Hollow Stem Auger/ODEX	NORTHING: 5977347.5 EASTING: 517664.1	ELEVATION: 137.4 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 / ◆ POCKET PEN (kPa) ◆ 100 200 300 400 / PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
30			BEDROCK *(continued)*					107
31					32			106
32					33			105
33			End of Hole at 33.2 m					104
34								103
35								102
36								101
37								100
38								99
39								98
40								97
41								96
42								95
43								94
44								93
45								

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-04**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B80/ODEX	NORTHING: 5977336.7 EASTING: 517781.8	ELEVATION: 137.4 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

■ GASTECH READINGS (PPM) ■ 200 400 600 800
▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80
PLASTIC M.C. LIQUID 20 40 60 80

DEPTH (m)	SPT "N"	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
0		FILL, shotrock	GRAB	1			137
1		ORGANICS, wood, roots, peat, black, moist	GRAB	2			136
1.5		CLAY, trace silt, trace angular gravel, low to intermediate plasticity, hard, grey, moist	SPLIT SPOON	3	100	Enviro sampler used	
2	38	-becomes siltier with depth, changes to brown	SPLIT SPOON	4	92		135
3		-dry to moist	SPLIT SPOON	5	100	Enviro sampler used	134
3.5	22		SPLIT SPOON	6	92		
4			SPLIT SPOON	7	83	Enviro sampler used	133
5	6	-becomes silty, intermediate plasticity, soft, fissured, laminated, grey, wet	SPLIT SPOON	8	100		132
6			SPLIT SPOON	9	85	Enviro sampler used	131
6.5			TUBE	10	50		
7.5		-some angular to round gravel -13mm layer of coarse grey sand -silt pockets	SPLIT SPOON	11	100	Enviro sampler used	130
8.7			TUBE	12	0	refusal with Shelby tube	129
9		-very soft, grey, very wet	SPLIT SPOON	13	71	Enviro sampler used	128
9.5	27	CLAY, with silt interbeds, some sand to sandy, trace gravel, compact, brown, wet	SPLIT SPOON	14	46		
10.5	4		SPLIT SPOON	15	100	Grain Size Analysis Gravel: 5% Sand: 22% Silt: 52% Clay: 21%	127
11.8		GRAVEL, trace fines, angular to rounded	GRAB	17	0	hole sloughed 60cm when sampler was put down hole refusal with split spoon	126
12.5			GRAB	18			125
13.3		BEDROCK					124
14			GRAB	19			123
15							

amec	AMEC Earth & Environmental 2227 Douglas Road Burnaby, British Columbia CANADA, V5C 5A9	LOGGED BY: GM ENTERED BY: BP	COMPLETION DEPTH: 17.7 m COMPLETION DATE: 7/9/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-04**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B80/ODEX	NORTHING: 5977336.7 EASTING: 517781.8	ELEVATION: 137.4 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m)	■ GASTECH READINGS (PPM) ■ 200 400 600 800 / ▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
15			BEDROCK *(continued)*		20			122
16								121
17					21			120
18			End of Hole at 17.8 m					119
19								118
20								117
21								116
22								115
23								114
24								113
25								112
26								111
27								110
28								109
29								108
30								

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CANADA, V5C 5A9

LOGGED BY: GM	COMPLETION DEPTH: 17.7 m
ENTERED BY: BP	COMPLETION DATE: 7/9/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-05**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B80/ODEX	NORTHING: 5977282.2 EASTING: 517914.6	ELEVATION: 145.6 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80
PLASTIC M.C. LIQUID 20 40 60 80

DEPTH (m)	SPT "N"	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
0		FILL, shotrock				2" split spoon used for Enviro sampling	145
		ORGANICS, some wood, black, moist					
1	12	CLAY, silty, low to intermediate plasticity, stiff to hard, brown, moist	Split spoon	1	88		
2	23	-trace gravel	Split spoon	2	100	Grain Size Analysis Gravel: 4% Sand: 8% Silt: 55% Clay: 33%	144
	37	-hard to stiff	Split spoon	3	88		143
3	23		Split spoon	4	80		142
4	18		Split spoon	5	88		
5	14	-trace gravel -becomes firm, intermediate to high plasticity, wet	Split spoon	6	100		141
	9		Split spoon	7	100		140
6			Tube	8	100		139
7	5		Split spoon	9	100	sampler sank 100mm under weight of rods	138
8			Tube	10	100		137
9	13	-trace silt	Split spoon	11	100	sampler sank 50mm under weight of rods	136
10			Tube	12	100		
	6	-laminated	Split spoon	13	100	sampler sank 50mm under weight of rods	135
11			Tube	14	100		134
12	7	-becomes soft to firm, trace silt, intermediate to high plasticity, laminated, dark grey, wet	Split spoon	15	100	sampler sank 76mm under weight of rods	133
13			Tube	16	100		
	4		Split spoon	17	100	sampler sank 76mm under weight of rods	132
14			Tube	18	100		131
15							

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LOGGED BY: GM	COMPLETION DEPTH: 23.0 m
ENTERED BY: BP	COMPLETION DATE: 7/8/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-05**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B80/ODEX	NORTHING: 5977282.2 EASTING: 517914.6	ELEVATION: 145.6 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80; PLASTIC M.C. LIQUID 20 40 60 80

DEPTH (m)	SPT "N"	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
15	5	CLAY, silty, low to intermediate plasticity, stiff to hard, brown, moist *(continued)*	Split spoon	19	100	sampler sank 150mm under weight of rods, sank an additional 125mm under weight of hammer	130
			Tube	20	0	refusal with Shelby tube	
16	33	-gravelly	Split spoon	21	38		129
17	35	SAND and GRAVEL, clean, angular, dense, grey, wet	Split spoon	22	58		128
18		BEDROCK	Grab	23		refusal with wing bit, advanced casing to 18.3m	127
21			Grab	24			124
23		End of Hole at 23.0 m					

Depth scale: 15–30 m; Elevation scale: 130–116 m

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LOGGED BY: GM	COMPLETION DEPTH: 23.0 m
ENTERED BY: BP	COMPLETION DATE: 7/8/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-06**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B80/ODEX	NORTHING: 5977171.1 EASTING: 517916.3	ELEVATION: 144 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m)	SPT "N" (BLOWS/300 mm) 20 40 60 80; PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
0			FILL, shot rock, 300mm maximum diameter				2" split spoon used for Enviro samples	
			ORGANICS, some wood, fibrous, black, moist					
1	24		CLAY, trace gravel, hard, low to intermediate plasticity, laminated, dark brown, moist	Split spoon	1	100		143
2	52		-becomes stiff	Split spoon	2	100		142
	15			Split spoon	3	30		
3			BEDROCK	Grab			refusal with split spoon	141
4				Grab	4			140
5				Grab	5			139
6								138
7				Grab	6			137
			End of hole at 7.6 m					
8								136
9								135
10								134
11								133
12								132
13								131
14								130
15								

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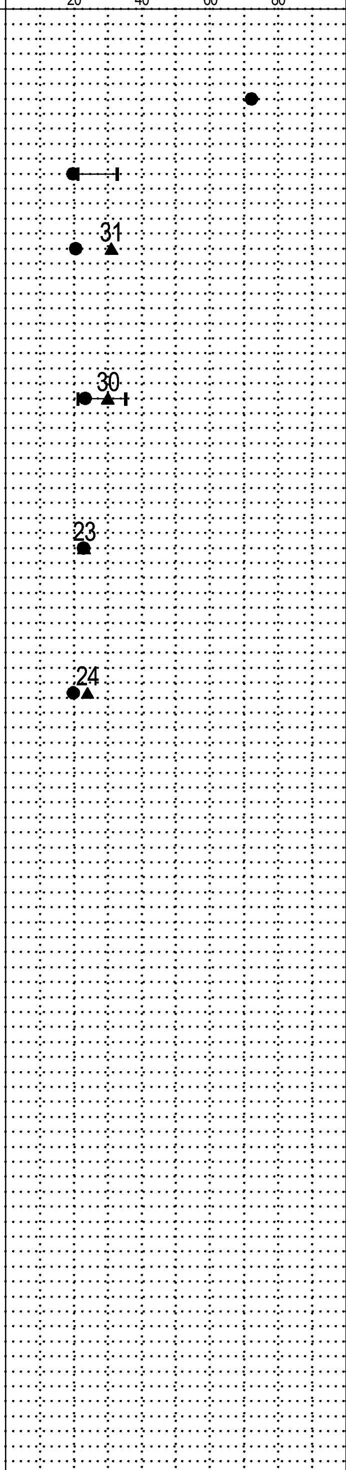
LOGGED BY: GM	COMPLETION DEPTH: 7.6 m
ENTERED BY: BP	COMPLETION DATE: 7/6/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-07**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B80/ODEX	NORTHING: 5977091.9 EASTING: 517909.1	ELEVATION: 143.5 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80

PLASTIC M.C. LIQUID 20 40 60 80



DEPTH (m)	SOIL DESCRIPTION	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
0	FILL, shotrock up to 300mm diameter				143
1	PEAT, some wood, organics, fibrous, dark brown, moist	1	63	sample taken with Enviro spoon	
	CLAY, silty, trace sand, trace gravel, low to intermediate plastic, stiff to hard, dark brown, moist -1mm thick fine to coarse grained sand layer -30mm sand pocket, very fine grained, loose, grey to green, dry	2	83	sample taken with Enviro spoon Grain Size Analysis Gravel: 2% Sand: 6% Silt: 52% Clay: 40%	142
2		3	88		141
3	-30mm diameter round gravel	4	100	sample taken with Enviro spoon	140
4		5	83	Atterberg Limits Liquid Limit: 35% Plastic Limit: 21%	
		6	100	sample taken with Enviro spoon	139
5	-becomes dark grey	7	92		138
6	-becomes light brown	8	92	sample taken with Enviro spoon Grain Size Analysis Gravel: 1% Sand: 16% Silt: 47% Clay: 36%	137
7	-trace fine gravel, uniform, dark grey, moist	9	83	refusal with SPT	136
	GRAVEL, trace clay BEDROCK			refusal with drill bit, advanced casing to 7.5m	
8		10			135
9					134
10		11			133
11		12			132
12					131
13		13			130
14	End of Hole at 13.7m				129
15					

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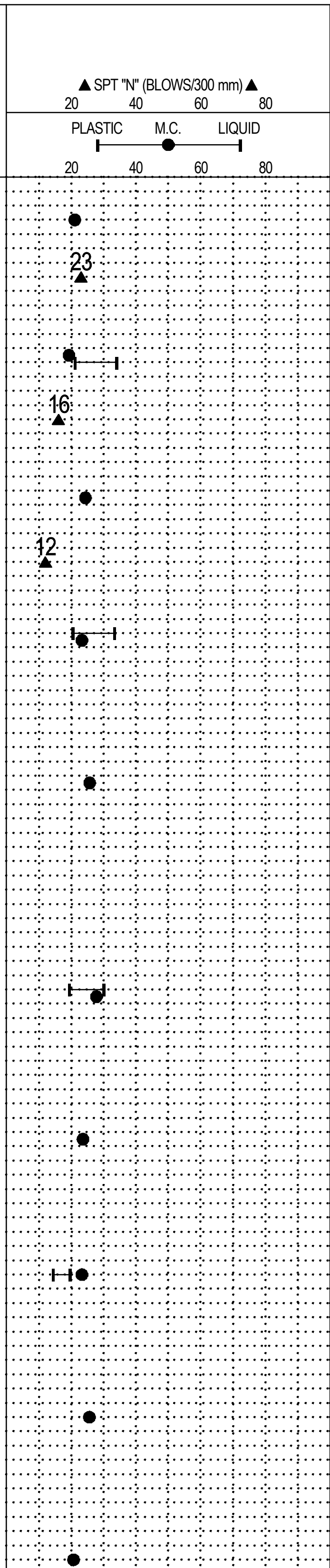
LOGGED BY: GM	COMPLETION DEPTH: 13.7 m
ENTERED BY: BP	COMPLETION DATE: 7/9/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-08**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: M5T/Hollow Stem Auger/ODEX	NORTHING: 5977249.9 EASTING: 517960.3	ELEVATION: 143.5 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN



DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
0	ORGANICS, woody debris					143.5
	CLAY, silty, trace gravel, trace sand, very stiff, low plasticity, dark brown to grey, moist	Split spoon	1	100	sampled with Enviro spoon	143
1		Split spoon	2	80		
2		Split spoon	3	88	sampled with Enviro spoon Grain Size Analysis Gravel: 2% Sand: 6% Silt: 53% Clay: 39%	142 / 141
		Split spoon	4	83		
3	-moist to wet	Split spoon	5	80	sampled with Enviro spoon	140
4	-2-4mm thick sand pockets, moist to wet	Split spoon	6	77		139
5		Split spoon	7	75	sampled with Enviro spoon Grain Size Analysis Sand: 4% Silt: 52% Clay: 44%	138
		Tube	8			
6		Split spoon	9	92	sampled with Enviro spoon, spoon sank 30mm under weight of rods, top of sample shows disturbed clay possibly from bottom of Shelby	137
7		Tube		0	no recovery in Shelby tube, drilled to 7.62m to try again after cleaning ball valve on Shelby attachment	136
8		Tube	10	100		
	-trace very fine sand	Split spoon	11	100	sampled with Enviro spoon	135
9	-some silt to silty, soft, wet	Tube	12	50	Shelby tube sank 300mm under weight of rods	134
10	-soft to firm, moist to wet	Split spoon	13	100		133
11		Tube	14	100		
	-wet, above liquid limit when remoulded	Split spoon	15	100	Grain Size Analysis Sand: 5% Silt: 66% Clay: 29%	132
12		Tube	16	100	Shelby tube sank 360mm under weight of rods	131
13	-silty, trace fine gravel, very soft, wet (moisture above liquid limit)	Split spoon	17	100	noticed material in casing to appoximately 11m, cleaned out clay chunks with split spoon before sampling	130
14		Tube		0	sampled with Enviro spoon Shelby tube sat 360mm above bottom of hole and after pushing for 60mm the Shelby tube sank 600mm under the weight of rods	129
	SILT and SAND interbeds, firm to loose, brown, saturated	Tube		0		
15						

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LOGGED BY: NE/DL	COMPLETION DEPTH: 25.6 m
ENTERED BY: BP	COMPLETION DATE: 7/8/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-08**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: M5T/Hollow Stem Auger/ODEX	NORTHING: 5977249.9 EASTING: 517960.3	ELEVATION: 143.5 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80
PLASTIC M.C. LIQUID 20 40 60 80

DEPTH (m)	SPT "N"	SOIL DESCRIPTION	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
15		SILT and SAND interbeds, firm to loose, brown, saturated *(continued)* -thin clay layer < 0.2 m -thin clay layer < 0.2 m		10	refusal with Shelby tube, no recovery in tube no resistance to augers while drilling to 14.5m sampled with Enviro spoon Grain Size Analysis Sand: 47% Silt: 53%	128, 127
17	9		19	80		126
17.5		SAND, silty, some angular gravel, trace clay, uniform, dense, brown, wet				
18.5	38		20	58	heavy grinding with drill bit, possible large rock fragments	125, 124
19.8					Grain Size Analysis Gravel: 15% Sand: 42% Silt: 34% Clay: 9%	
20	13	CLAY, silty, trace to some gravel, angular, grey, wet	21	100	noted one 25mm long rounded gravel fragment	123
20.4		GRAVEL	23		switched to open hole drilling	122
21.8		BEDROCK	24, 25, 26, 27			121, 120, 119, 118
25.9		End of Hole at 25.9 m				117, 116, 115, 114

DEPTH scale: 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

BOREHOLE LOG EG09260-4220-DH-GATEWAY.GPJ AMEC PG.GDT 5/19/09

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LOGGED BY: NE/DL	COMPLETION DEPTH: 25.6 m
ENTERED BY: BP	COMPLETION DATE: 7/8/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-09**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: M5T/ODEX	NORTHING: 5978094 EASTING: 517934.8	ELEVATION: 181.5 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80
PLASTIC M.C. LIQUID 20 40 60 80

DEPTH (m)	SPT "N"	SOIL DESCRIPTION	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
0		FILL, loose angular shot rock			drilled 0.3 m before sampling	
	>>16	SAND, some silt, some organics, trace to some gravel, reddish brown, moist	1	33	sample taken with Enviro spoon	181
			2		refusal with Enviro spoon	
1		-some sand and gravel, dry			a lot of dust	180
2			3			179
3		- trace reddish sand, some small sub-rounded stones (#50), angular, sharp, grey, dry	4			178
4			5			177
5		BEDROCK	6			176
6			7			175
7						174
8			8			173
9			9			172
10		End of Hole at 10.2 m			Note: due to location of DH, results may indicate an old logging road or possible rock slide	171
11						170
12						169
13						168
14						167
15						

BOREHOLE LOG EG09260-4220-DH-GATEWAY.GPJ AMEC PG.GDT 5/19/09

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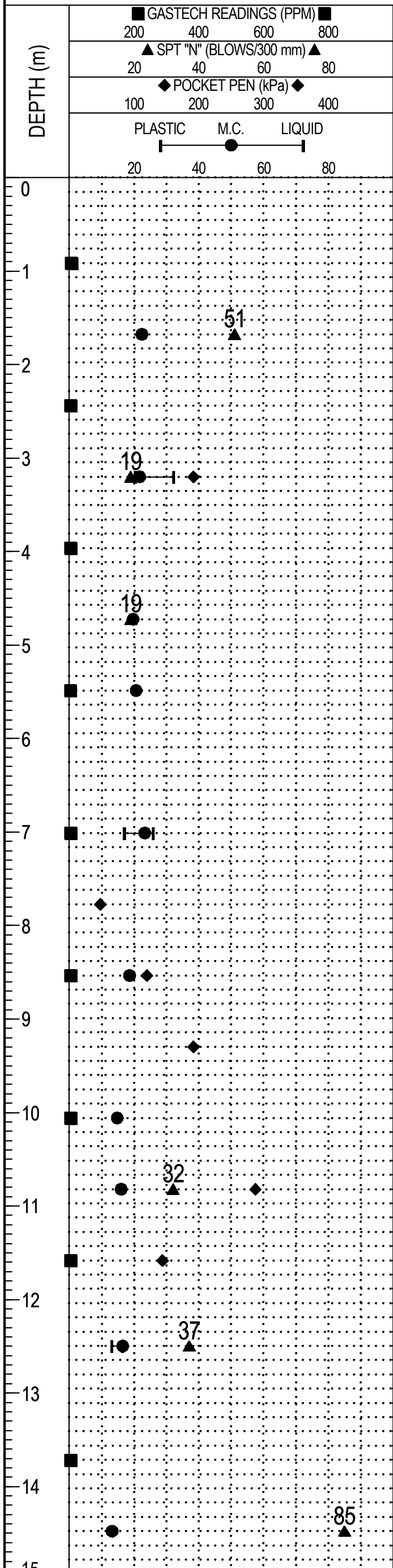
LOGGED BY: GM	COMPLETION DEPTH: 10.2 m
ENTERED BY: BP	COMPLETION DATE: 7/15/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-10**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B80/ODEX	NORTHING: 5977580.9 EASTING: 518640.5	ELEVATION: 92.9 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN



SOIL DESCRIPTION	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
FILL, shotrock, some clay, some organics, brown, wet				
CLAY, silty, some sand, trace gravel, hard to stiff, intermediate plasticity, brown, moist to wet	1	96	Enviro sampler used	92
-stiff	2	25		91
	3	75	Enviro sampler used	
	4	88	Grain Size Analysis Gravel: 3% Sand: 7% Silt: 52% Clay: 38%	90
	5	79	Enviro sampler used	89
	6	100		88
	7	100	Enviro sampler used	
-becomes siltier	8	100		87
-soft	9	100	Enviro sampler used Grain Size Analysis Gravel: 4% Sand: 5% Silt: 59% Clay: 32%	86
	10	38		85
-firm	11	100	Enviro sampler used	
CLAY and SILT, trace sand, trace gravel, firm, low plasticity, brown, wet	12	100		84
	13	100	Enviro sampler used	83
SILT, clayey, some sand, trace to some gravel, stiff, low plasticity, brown, wet	14	79		82
-firm	15	100	Enviro sampler used	81
	16	67	Grain Size Analysis Gravel: 10% Sand: 15% Silt: 56% Clay: 19% Enviro sampler used	80
-some gravel	17	100		79
SAND and SILT, hard	18	75		78

AMEC Earth & Environmental 2227 Douglas Road Burnaby, British Columbia CANADA, V5C 5A9	LOGGED BY: SC/DL	COMPLETION DEPTH: 32.9 m
	ENTERED BY: BP	COMPLETION DATE: 7/16/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-10**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B80/ODEX	NORTHING: 5977580.9 EASTING: 518640.5	ELEVATION: 92.9 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Column headings: DEPTH (m) | GASTECH READINGS (PPM) 200 400 600 800; SPT "N" (BLOWS/300 mm) 20 40 60 80; POCKET PEN (kPa) 100 200 300 400; PLASTIC M.C. LIQUID 20 40 60 80 | SOIL SYMBOL | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE NO | RECOVERY (%) | ADDITIONAL INFORMATION | ELEVATION (m)

DEPTH (m)	SOIL DESCRIPTION	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
15	SAND and SILT, hard *(continued)*			
	SAND and GRAVEL, trace silt, trace clay	19		77
17		20		76
18		21	increased casing depth to 18m	75
19		22	difficult to push hammer	74
20		23		73
		24		
21				72
22				71
23				70
24			gravel sloughing pushed casing to 24m, not enough cuttings for sample	69
25				68
26		25		67
27		26		66
28				65
	BEDROCK			
29		27		64
30				63

Depth scale: 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-10**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B80/ODEX	NORTHING: 5977580.9 EASTING: 518640.5	ELEVATION: 92.9 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

GASTECH READINGS (PPM): 200 400 600 800
SPT "N" (BLOWS/300 mm): 20 40 60 80
POCKET PEN (kPa): 100 200 300 400
PLASTIC M.C. LIQUID: 20 40 60 80

DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
30		BEDROCK *(continued)*					
31							62
32			GRAB	28			61
33		End of Hole at 32.9 m					60
34							59
35							58
36							57
37							56
38							55
39							54
40							53
41							52
42							51
43							50
44							49
45							48

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-11**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: M5T/ODEX	NORTHING: 5978036.5 EASTING: 517733.1	ELEVATION: 157.2 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m)	▲SPT "N" (BLOWS/300 mm)▲ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
0	5		ORGANICS, trace gravel (30mm diameter), soft, dark brown -thin layer of coarse sand	SPLIT SPOON	1	50	sample taken with Enviro spoon	157
0.6			BEDROCK	GRAB	2			156
				GRAB	3			155
				GRAB	4			154
5.2			End of Hole at 5.2 m					152

Depth scale: 0–15 m; Elevation scale: 157–143 m.

AMEC Earth & Environmental 2227 Douglas Road Burnaby, British Columbia CANADA, V5C 5A9	LOGGED BY: GM ENTERED BY: BP	COMPLETION DEPTH: 5.2 m COMPLETION DATE: 7/15/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-12**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: M5T/Hollow Stem Auger/ODEX	NORTHING: 5977942.7 EASTING: 517733.6	ELEVATION: 160.5 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m)	▲SPT "N" (BLOWS/300 mm)▲ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
0	12		ORGANICS, some branches and roots, peat, stiff, reddish brown, wet -dense reddish sand, some clay and roots	Split spoon	1	100	sample taken with Enviro spoon	160
1			SAND and GRAVEL, dense				refusal with Enviro spoon	
1.2			BEDROCK	Grab	2			159
				Grab	3			
				Grab	4			
5.8			End of Hole at 5.8 m					

Depth scale: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Elevation scale: 160 159 158 157 156 155 154 153 152 151 150 149 148 147 146

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CANADA, V5C 5A9

LOGGED BY: GM	COMPLETION DEPTH: 5.8 m
ENTERED BY: BP	COMPLETION DATE: 7/14/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-13**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977580 EASTING: 517804	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)	DEPTH (m)
0							**OVERBURDEN**							
1			61	0			**DIORITE** with quartz/felsic veining up to 0.15 m thick, pyrite on fractures, reddish oxidation near surface							1
2			100	70										2
3														3
4			100	80										4
5			100	48										5
6							**FELSIC DYKE**, slightly weathered biotite, white-cream coloured							6
7			100	31			**DIORITE**							7
							ANDESITE DYKE							
8			100	93										8
9														9
10							**DIORITE,** occasional disseminated sulphides							

AMEC ROCK EG09260-4220-DH-ROCK-GATEWAY.GPJ AMEC PG WITH ROCK.GDT 5/19/09

amec	AMEC Earth & Environmental 2227 Douglas Road Burnaby, British Columbia CANADA, V5C 5A9	LOGGED BY: DL ENTERED BY: KB	COMPLETION DEPTH: 46.2 m COMPLETION DATE: 7/28/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-13**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977580 EASTING: 517804	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
10			100	69			**DIORITE,** occasional disseminated sulphides *(continued)*								
11															11
12			100	98											12
13			100	68											13
14							-Felsic/mafic banding beginning at 14.2 m								14
15			100	91											15
16							**FELSIC DYKE** -Frequent diorite xenoliths								16
			100	73 (est)			**DIORITE**								
17															17
18			100	95 (est)											18
							FELSIC DYKE, increasing mafics, coarsening with depth								
19															19
20			100	70											

amec

AMEC Earth & Environmental
2227 Douglas Road
Burnaby, British Columbia
CANADA, V5C 5A9

LOGGED BY: DL	COMPLETION DEPTH: 46.2 m
ENTERED BY: KB	COMPLETION DATE: 7/28/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-13**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977580 EASTING: 517804	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
20							**FELSIC DYKE**, increasing mafics, coarsening with depth *(continued)*								
21			100	85											21
							GRANITE to GRANODIORITE, quartz rich, some carbonate infilling on joints -Occasional small diorite xenoliths								
22															22
			100	83											
23															23
24			100	96											24
25															25
			100	88											
26															26
27			100	90											27
28															28
			100 (est)	76											
29															29
30															

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-13**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977580 EASTING: 517804	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
30			100 (est)	35			**GRANITE to GRANODIORITE**, quartz rich, some carbonate infilling on joints -Occasional small diorite xenoliths *(continued)*								
31			100 (est)	70											31
32															32
33			100 (est)	61											33
34			100	96											34
35															35
36			100	71											36
37			100	59 (est)											37
38															38
39			100	76 (est)											39
40															

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LOGGED BY: DL	COMPLETION DEPTH: 46.2 m
ENTERED BY: KB	COMPLETION DATE: 7/28/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-13**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977580 EASTING: 517804	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
40–41.5			100	71			**GRANITE to GRANODIORITE**, quartz rich, some carbonate infilling on joints -Occasional small diorite xenoliths *(continued)*								41
41.5–43			100	93			**DIORITE**, fine to medium grained, occasional felsic veining								42
43–44.5			100	73			-Massive pyrite vein at contact **GRANITE to GRANODIORITE**, quartz rich, some carbonate infilling on joints								43, 44
44.5–46.2			100	96			**DIORITE**, fine to medium grained								45, 46
46.2							End of Hole at 46.2 m								47, 48, 49

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Burnaby, British Columbia
CANADA, V5C 5A9

LOGGED BY: DL	COMPLETION DEPTH: 46.2 m
ENTERED BY: KB	COMPLETION DATE: 7/28/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-14**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977683 EASTING: 517886	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
0							**OVERBURDEN**								
1															1
2															2
3							**DIORITE to GABBRO**, medium grained, occasional felsic veining, pyrite and slight chloritization on joints								3
4			100	73											4
5															5
6			100	68											6
7			100	66											7
8															8
9			100	93											9
10							-Minor local pyrite at 9.8 m								

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-14**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977683 EASTING: 517886	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
10			100	81			**DIORITE to GABBRO**, medium grained, occasional felsic veining, pyrite and slight chloritization on joints *(continued)*								
11															11
12			100	90											12
13			100	68			-Felsic dyke ~75 mm thick at 13.6 m								13
14															14
15			100	91											15
16			100	78			- Pyrite at 16.5 m								16
17															17
18			100	86											18
19			100	78											19
20															

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-14**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977683 EASTING: 517886	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
20							**DIORITE to GABBRO**, medium grained, occasional felsic veining, pyrite and slight chloritization on joints *(continued)*								
21			100	98											21
22															22
			100	88			**DIORITE to GABBRO**, medium to coarse grained, carbonate infilling on joints								
23															23
24			100	93											24
25							**DIORITE**, fine grained, black, carbonate infilling on joints								25
26			100	85											26
27			100	93											27
28															28
29			100	56											29
30															

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-14**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977683 EASTING: 517886	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)	DEPTH (m)
30			100	91			**DIORITE**, fine grained, black, carbonate infilling on joints *(continued)*							
31			100	71										31
32														32
33			100	78			**FELSIC DYKE**							33
							GRANODIORITE, some pyrite on joints							
34			100	78										34
35														35
36			100	95										36
37			100	83										37
38														38
39			100	61										39
40														

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LOGGED BY: DL	COMPLETION DEPTH: 43.6 m
ENTERED BY: KB	COMPLETION DATE: 7/23/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-14**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977683 EASTING: 517886	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
40							**GRANODIORITE**, some pyrite on joints *(continued)*								
41			100	63											41
42			100	66											42
43															43
							End of Hole at 43.6 m								
44															44
45															45
46															46
47															47
48															48
49															49
50															

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-15**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977623 EASTING: 517976	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying 'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
0							**OVERBURDEN**								
1							**DIORITE**, fine grained, black, frequent felsic veining								1
2			n/a	n/a											2
3			100	54											3
4															4
5			100	61											5
6			100 (est)	80 (est)											6
7															7
8			100	90											8
9			100	93											9
10															

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-15**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977623 EASTING: 517976	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
10							**DIORITE**, fine grained, black, frequent felsic veining *(continued)*								
11			100	43											11
12							**FELSIC DYKE**								12
			100	50 (est)											
13							**GRANODIORITE**								13
14							**ANDESITE** with plagioclase phenocrysts								14
			100 (est)	14 (est)											
15															15
16			0	n/a											16
17			100 (est)	88											17
18							**FELSIC DYKE**								18
19			100 (est)	23											19
20															

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-15**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977623 EASTING: 517976	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
20			100	38			**FELSIC DYKE** *(continued)*								
							DIORITE with felsic veining, some sulfide veining								
21															21
			100	83											
22															22
23			100	91											23
24															24
25			100	56											25
							FELSIC DYKE								
26			100	41											26
27															27
28			100	35											28
							ANDESITE, fine grained, dark grey, with plagioclase phenocrysts								
29															29
			100 (est)	48											
							QUARTZ DIORITE with felsic veining up to 50 mm thick								
30															

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-15**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977623 EASTING: 517976	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)	DEPTH (m)
30							**QUARTZ DIORITE** with felsic veining up to 50 mm thick *(continued)*							
31			100 (est)	80			-Massive sulphide veining at 30.9 m							31
32			100 (est)	56										32
33–34			96 (est)	63										33–34
35			100 (est)	70 (est)										35
36							**ANDESITE DYKE**, fine grained, black, some plagioclase phenocrysts							36
36.5							**QUARTZ DIORITE**, with felsic veining up to 50 mm thick							
37			100 (est)	96 (est)										37
38			100	86										38
39							**ANDESITE DYKE**, fine grained, black, trace plagioclase phenocrysts							39
40														

AMEC ROCK EG09260-4220-DH-ROCK-GATEWAY.GPJ AMEC PG WITH ROCK.GDT 5/19/09

amec	AMEC Earth & Environmental 2227 Douglas Road Burnaby, British Columbia CANADA, V5C 5A9	LOGGED BY: DL ENTERED BY: KB	COMPLETION DEPTH: 42.1 m COMPLETION DATE: 7/19/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-15**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: BBS 18/Diamond Drill NQ	NORTHING: 5977623 EASTING: 517976	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
40			100	75			**ANDESITE DYKE**, fine grained, black, trace plagioclase phenocrysts *(continued)*								
41			100	61 (est)											41
42							End of Hole at 42.1 m								42
43															43
44															44
45															45
46															46
47															47
48															48
49															49
50															

amec

AMEC Earth & Environmental
2227 Douglas Road
Burnaby, British Columbia
CANADA, V5C 5A9

LOGGED BY: DL	COMPLETION DEPTH: 42.1 m
ENTERED BY: KB	COMPLETION DATE: 7/19/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-16**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5978176 EASTING: 518367	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
0							**QUARTZ DIORITE**, medium grained								
1			25	4											1
3			100	39	26										3
4							**FELSIC DYKE**								4
4.5			75	0	20										
5							**QUARTZ DIORITE** with pyrite veining								5
5.6			100	78	9										
7			100	78	10										7
8.3							-Rusty oxidation between 8.2 m and 8.8 m								
8.7			100	15	19										
9							**FELSIC DYKE**								9
10															

AMEC ROCK EG09260-4220-DH-ROCK-GATEWAY.GPJ AMEC PG WITH ROCK.GDT 5/19/09

AMEC Earth & Environmental 2227 Douglas Road Burnaby, British Columbia CANADA, V5C 5A9	LOGGED BY: DL	COMPLETION DEPTH: 33.8 m
	ENTERED BY: KB	COMPLETION DATE: 10/19/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-16**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5978176 EASTING: 518367	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
10							**FELSIC DYKE** *(continued)*								
							QUARTZ DIORITE								
11			100	85	35										11
							-Frequent pyrite at 11.3 m								
12															12
13			100 (est)	36 (est)											13
14															14
15			100	100	12		-Felsic dyke from 15.5 m to 15.6 m								15
16															16
17							-Quartz vein from 17 m to 17.3 m								17
							FELSIC DYKE								
18			100	86	12										18
							QUARTZ DIORITE								
19															19
			100	85	17										
20															

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-16**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5978176 EASTING: 518367	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
20							**QUARTZ DIORITE** *(continued)*								
							DIORITE, rusty brown weathered joints								
21			100	43	15										21
22			100	0	10										22
							FELSIC DYKE								
23							**QUARTZ DIORITE**								23
			100	94	52										
24															24
25															25
26			100	100	41										26
27															27
28															28
29			100	93	34										29
30															

AMEC ROCK EG09260-4220-DH-ROCK-GATEWAY.GPJ AMEC PG WITH ROCK.GDT 5/19/09

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-16**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5978176 EASTING: 518367	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
30							**QUARTZ DIORITE** *(continued)*								
31							-Felsic intrusion from 31 m to 31.1 m								31
32			100	98	42										32
33															33
34							End of Hole at 33.8 m								34
35															35
36															36
37															37
38															38
39															39
40															

AMEC ROCK EG09260-4220-DH-ROCK-GATEWAY.GPJ AMEC PG WITH ROCK.GDT 5/19/09

amec	AMEC Earth & Environmental 2227 Douglas Road Burnaby, British Columbia CANADA, V5C 5A9	LOGGED BY: DL ENTERED BY: KB	COMPLETION DEPTH: 33.8 m COMPLETION DATE: 10/19/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-17**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5977139 EASTING: 518723	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
0							**OVERBURDEN**								
1															1
2							**GRANITE**, medium grained, brownish white								2
3			100 (est)	37											3
4			75 (est)	0	9		**ULTRAMAFICS**, medium to coarse grained, dark green								4
5															5
6			45 (est)	44	13										6
7			100 (est)	44	18		-Felsic dyke from 7.0 m to 7.2 m								7
8							-Large bluish plagioclase phenocrysts from 7.9 m to 12 m								8
9			90 (est)	67 (est)	8										9
10															

AMEC ROCK EG09260-4220-DH-ROCK-GATEWAY.GPJ AMEC PG WITH ROCK.GDT 5/19/09

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-17**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5977139 EASTING: 518723	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
10			100 (est)	75 (est)	19		**ULTRAMAFICS**, medium to coarse grained, dark green *(continued)*								
11							-Sandy clay gouge <1 cm thick at 11.4 m								11
12			100 (est)	60 (est)	13		**GRANITE**, bleached white								12
13			100 (est)	43	19		**ULTRAMAFICS**, dark green								13
14															14
15			100 (est)	89	19		**QUARTZ DYKE**								15
16															16
17							**ULTRAMAFICS**, dark green								17
18			100 (est)	62	18										18
19															19
20															

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-17**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5977139 EASTING: 518723	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
20			100 (est)	41	36		**ULTRAMAFICS**, dark green *(continued)* -Quartz dyke from 20.4 m to 20.6 m								
21			100 (est)	41	11										21
22			100 (est)	77	20		**QUARTZ DYKE**								22
23			100 (est)	77	36		**ULTRAMAFICS**, dark green								23
24															24
25			100 (est)	85	17										25
26							**QUARTZ DIORITE DYKE**								26
							ULTRAMAFICS, dark green								
27			100 (est)	62	14										27
28															28
29							-Gneissic banding (Quartz Diorite bands), pyrite on joint surfaces and along veins beginning at 29.4 m								29
30															

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-17**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5977139 EASTING: 518723	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
30			100 (est)	88			**ULTRAMAFICS**, dark green *(continued)*								
31															31
32			100 (est)	55	21										32
33															33
34			100 (est)	65	18										34
35															35
36			100 (est)	85	32										36
37															37
38			100 (est)	65	18										38
39															39
40															

AMEC ROCK EG09260-4220-DH-ROCK-GATEWAY.GPJ AMEC PG WITH ROCK.GDT 5/19/09

amec	AMEC Earth & Environmental 2227 Douglas Road Burnaby, British Columbia CANADA, V5C 5A9	LOGGED BY: GM ENTERED BY: KB	COMPLETION DEPTH: 46.7 m COMPLETION DATE: 10/22/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-17**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5977139 EASTING: 518723	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
40			90 (est)	38	14		**ULTRAMAFICS**, dark green *(continued)*								
41															41
							QUARTZ DIORITE with granitic intrusions								
42			90 (est)	85 (est)	20										42
43															43
44															44
45			100 (est)	98 (est)	26										45
46															46
47							End of Hole at 46.8 m								47
48															48
49															49
50															

AMEC ROCK EG09260-4220-DH-ROCK-GATEWAY.GPJ AMEC PG WITH ROCK.GDT 5/19/09

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-18**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5977260 EASTING: 518761	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
0							**OVERBURDEN**								
1															1
							QUARTZ DIORITE, medium grained, bluish grey								
2			44	38	29										2
3			91	27	44										3
			100	26	16		-Felsics and local quartz veining at 3.7 m								
4															4
			97	35	28										
5							-Numerous quartz veins up to 50 mm thick at 5.2 m								5
6															6
			95	77	22										
7															7
8							-Pyrite at 8.3 m								8
9			100	67	13										9
10															

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-18**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5977260 EASTING: 518761	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
10							**QUARTZ DIORITE**, medium grained, bluish grey *(continued)* -Sulphide veining begins at ~10.2 m								
			100	59	14										
11							-Biotite banding, becomes more fine grained at 11.3 m								11
12			100	66	29										12
13			100	59	6										13
14															14
15			100	85	9										15
16			100	16	5		**FELSIC DYKE**, bleached white -Andesite dyke from 16.2 m to 16.5 m								16
17			100	45	17										17
			100	25	8										
18			100	63	21		**QUARTZ DIORITE** with felsic veining, grey								18
19															19
			66	0	20		**FELSIC DYKE**, bleached white								
20															

amec

AMEC Earth & Environmental
2227 Douglas Road
Burnaby, British Columbia
CANADA, V5C 5A9

LOGGED BY: DL	COMPLETION DEPTH: 40.8 m
ENTERED BY: KB	COMPLETION DATE: 10/24/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-18**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5977260 EASTING: 518761	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)	DEPTH (m)
20							**FELSIC DYKE**, bleached white *(continued)*							
			51	21	20									
21														21
							QUARTZ DIORITE, grey to black							
22														22
			100	88	18									
							FELSIC DYKE, quartz rich, white							
23														23
24			87	64	18									24
25			100	50	22									25
26			89	54	12		**DIORITE**, occasional massive sulphides on joints							26
27							-Pyrite at 26.8 m							27
			80	68	17									
28							-Calcite veinlets at 28 m							28
29			100	60	27									29
30														

amec	AMEC Earth & Environmental 2227 Douglas Road Burnaby, British Columbia CANADA, V5C 5A9	LOGGED BY: DL ENTERED BY: KB	COMPLETION DEPTH: 40.8 m COMPLETION DATE: 10/24/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-18**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5977260 EASTING: 518761	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)	DEPTH (m)
30							**DIORITE**, occasional massive sulphides on joints *(continued)*							
30.5			100	27	11									
31														31
32			97	56	34									32
32.3							-Pyrite at 32.3 m							
33														33
33.5			100	75	13									
34														34
35			100	86	10									35
36														36
36.3			100	70	19									
37							**FELSIC DYKE**							37
37.6			100	60	5		**QUARTZ DIORITE to DIORITE**, dark grey to black							
38														38
39			100	46	16									39
40														

AMEC ROCK EG09260-4220-DH-ROCK-GATEWAY.GPJ AMEC PG WITH ROCK.GDT 5/19/09

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-18**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: Hydracore 1800/Diamond Drill NQ	NORTHING: 5977260 EASTING: 518761	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)	DEPTH (m)
40			100	11	15		- Frequent Quartz veins at 39.8 m **QUARTZ DIORITE to DIORITE**, dark grey to black *(continued)*							
							End of Hole at 40.8 m							
41														41
42														42
43														43
44														44
45														45
46														46
47														47
48														48
49														49
50														

AMEC ROCK EG09260-4220-DH-ROCK-GATEWAY.GPJ AMEC PG WITH ROCK.GDT 5/19/09

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CANADA, V5C 5A9

LOGGED BY: DL	COMPLETION DEPTH: 40.8 m
ENTERED BY: KB	COMPLETION DATE: 10/24/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-20**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: M5T/Hollow Stem Auger/ODEX	NORTHING: 5977902.5 EASTING: 517551.1	ELEVATION: 153.2 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0		ORGANICS	GRAB	1	hand dug through organics	153
1		BEDROCK, quartz rich	GRAB	2	debris from upper part of hole falling in hole	152
2			GRAB		hard to hammer	151
3			GRAB	3		150
4			GRAB	4		149
5		End of Hole at 5.2 m				148
6						147
7						146
8						145
9						144
10						143
11						142
12						141
13						140
14						139
15						

BOREHOLE LOG EG09260-4220-DH-GATEWAY.GPJ AMEC PG.GDT 5/19/09

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LOGGED BY: GM	COMPLETION DEPTH: 5.2 m
ENTERED BY: BP	COMPLETION DATE: 7/17/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-22**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80 Truck/Odex/Diamond Drill NQ	NORTHING: 5977580 EASTING: 518758	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
0							**OVERBURDEN**								
							DIORITE with frequent quartz veining, medium grained, dark grey to blue								
1															1
2			100 (est)	93											2
3															3
4			100 (est)	96											4
5			100 (est)	96											5
6															6
							-Some pyrite/sulphides along veins beginning at 6.4 m								
7			100 (est)	96											7
8			100 (est)	97											8
9															9
10				100											

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-22**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80 Truck/Odex/Diamond Drill NQ	NORTHING: 5977580 EASTING: 518758	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)	DEPTH (m)
10			100 (est)				**DIORITE** with frequent quartz veining, medium grained, dark grey to blue *(continued)*							
11			100 (est)	100										11
12							**FELSIC DYKE** -Massive pyrite at 12.5 m							12
13			100 (est)	65			**DIORITE** with frequent quartz veining, medium grained, dark grey to black -Calcite/carbonate veining at 13.7m							13
14			100 (est)	47										14
15			100 (est)	99			-Random quartz veins beginning at 14.9 m							15
16							-Most joints infilled with carbonates beginning at 16.5m							16
17			100 (est)	55										17
18			100 (est)	97										18
19														19
20														

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LOGGED BY: GM	COMPLETION DEPTH: 97.2 m
ENTERED BY: KB	COMPLETION DATE: 7/13/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-22**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80 Truck/Odex/Diamond Drill NQ	NORTHING: 5977580 EASTING: 518758	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RECOVERY DATA: CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH: STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	DISCONTINUITY DATA: # OF JOINTS	(set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
20			100 (est)	82			**DIORITE** with frequent quartz veining, medium grained, dark grey to black *(continued)*								
21															21
22			100 (est)	100											22
23			100 (est)	97											23
24							-Quartz veins up to 50 mm thick from 24 m to 24.1 m								24
25			100 (est)	92 (est)											25
26			85 (est)	100			-Disseminated sulphides throughout beginning at 25.6 m								26
27			100	81	29										27
28			100	100	22										28
29															29
30															

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-22**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80 Truck/Odex/Diamond Drill NQ	NORTHING: 5977580 EASTING: 518758	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)	DEPTH (m)
30			100	90	29		**DIORITE** with frequent quartz veining, medium grained, dark grey to black *(continued)*							
31			100	98	21									31
32														32
33			100	93	17									33
34														34
35			100	80	11									35
36			100	93	14									36
37														37
38			100	86	17									38
39			100	90	27		**FELSIC DYKE**, mostly quartz -Open voids/vugs, weak zone at 39.5 m							39
40														

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-22**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80 Truck/Odex/Diamond Drill NQ	NORTHING: 5977580 EASTING: 518758	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)	DEPTH (m)
40							**FELSIC DYKE**, mostly quartz *(continued)*							
			100	100	16		**DIORITE** with frequent quartz veining, medium grained, dark grey to blue							
41							**FELSIC DYKE**							41
							DIORITE with frequent quartz veining, medium grained, dark grey to blue							
42			100	100										42
43														43
			100	100	16									
44														44
45			100	93	10									45
46														46
			100	53	11									
47														47
48			100	90	19									48
49														49
50			100	100	26									

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LOGGED BY: GM	COMPLETION DEPTH: 97.2 m
ENTERED BY: KB	COMPLETION DATE: 7/13/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-22**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80 Truck/Odex/Diamond Drill NQ	NORTHING: 5977580 EASTING: 518758	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
50							**DIORITE** with frequent quartz veining, medium grained, dark grey to blue *(continued)*								
51			100	86	25										51
52															52
53			100	100	11										53
54			100	100	14										54
55															55
56			100	96											56
57			100	96	15										57
58															58
59			100	93	23		-Large pegmatitic quartz crystals in open void at 58.7 m								59
60															

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CANADA, V5C 5A9

LOGGED BY: GM	COMPLETION DEPTH: 97.2 m
ENTERED BY: KB	COMPLETION DATE: 7/13/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-22**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80 Truck/Odex/Diamond Drill NQ	NORTHING: 5977580 EASTING: 518758	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)		DEPTH (m)
60			100	95	16		**DIORITE** with frequent quartz veining, medium grained, dark grey to blue *(continued)*								
61			100	96	18										61
62															62
63			100	95	22										63
64			100	100	14										64
65															65
66			100	86	13										66
67			100	90	19										67
68							**FELSIC DYKE**								68
69			100	100	24		**DIORITE**, dark grey to blue, medium grained, frequent quartz veining								69
							FELSIC DYKE								
70															

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)	DEPTH (m)
70							**FELSIC DYKE** *(continued)*							
71			100	96	33									71
72			100	85	30		**DIORITE**, dark bluish green, medium grained -Massive pyrite with weathered open vugs from 72.7 m to 73.6 m							72
73														73
74			100	96	23									74
75			100	96										75
76														76
77			100	86	18									77
78			100	53	14									78
79			100	76	22									79
80														

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-22**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80 Truck/Odex/Diamond Drill NQ	NORTHING: 5977580 EASTING: 518758	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)	DEPTH (m)
80							**DIORITE**, dark bluish green, medium grained *(continued)*							
81			100	60	32									81
82			100	47	24									82
83							-Fractured zone from 82.9 m to 86.3 m							83
			100 (est)	80 (est)			-50 mm thick clay fault gouge at 83.2 m, healed fault gouge from 83.2m to 83.3 m							
84			100	53	25									84
85			100	53	22		-Minor sandy gouge at 84.7 m -Frequent calcite veining/infilling, lots of open voids from 84.7 m to 86.3 m							85
86														86
87			100	81	22									87
88			100	30	40									88
89			100	46	19		**QUARTZ DIORITE**, bluish green							89
90														

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-22**
DRILLER: Geotech Drilling	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80 Truck/Odex/Diamond Drill NQ	NORTHING: 5977580 EASTING: 518758	ELEVATION:

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and requires interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commisioned and the accompanying'Explanation of Borehole Log'.

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	PHOTO LOG	CORE RUN	RECOVERY (%)	RQD (%)	RUN TIME (min)	ROCK UNITS	DESCRIPTION	STRENGTH INDEX	WEATHERING	$I_{S(50)}$(MPa)	UCS (MPa)	# OF JOINTS	DISCONTINUITY DATA (set number, relative orientation to set 1,dip, spacing, alteration, roughness, other)	DEPTH (m)
90							**QUARTZ DIORITE**, bluish green *(continued)*							
							-Large calcite/quartz crystals in open void, vuggy rock at 90.5 m							
91			100	43	19									91
92			100	66	38		**DIORITE**, bluish green							92
93			100	80	45		**FELSIC DYKE**							93
							DIORITE, bluish green							
94														94
95			100	71	19		**FELSIC DYKE**							95
							DIORITE, bluish green							
96			100	48	40									96
97							End of Hole at 97.2 m							97
98														98
99														99
100														

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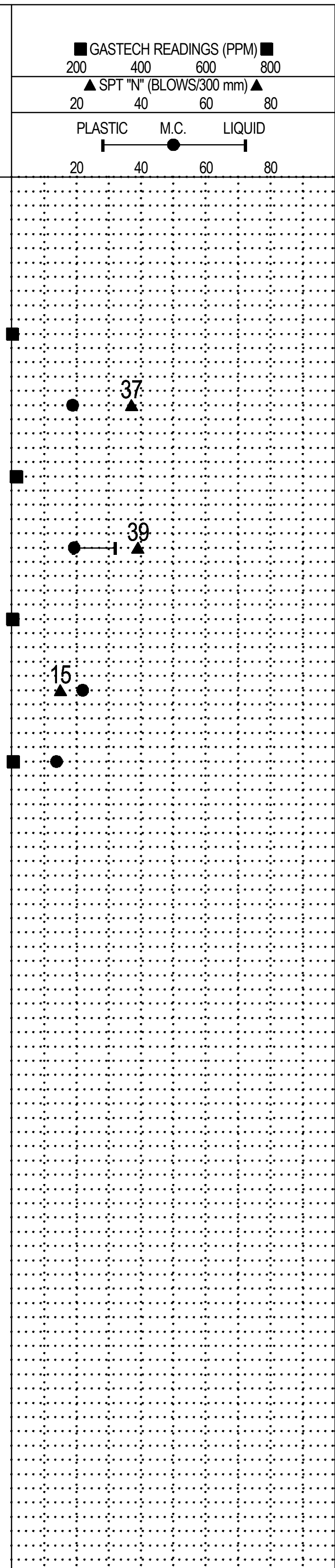
LOGGED BY: GM	COMPLETION DEPTH: 97.2 m
ENTERED BY: KB	COMPLETION DATE: 7/13/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH06-24**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B80/ODEX	NORTHING: 5977019.8 EASTING: 517919	ELEVATION: 143.9 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN



DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	ADDITIONAL INFORMATION	ELEVATION (m)
0	FILL, coarse shotrock					
1	ORGANICS					143
	CLAY, silty, sandy, some roots, some gravel, angular to sub-rounded, hard, intermediate plasticity, grey, moist	SPLIT SPOON	1	75	Enviro sampler used	
2		SPLIT SPOON	2	100	Grain Size Analysis Gravel: 3% Sand: 40% Silt: 42% Clay: 15%	142
3		SPLIT SPOON	3	92	Enviro sampler used	141
4	-trace gravel (#50), angular -becomes silty, hard, intermediate plasticity, moist to wet	SPLIT SPOON	4	80		140
5	-hard, low plasticity, brown, moist -sub-rounded 15mm gravel in clay	SPLIT SPOON	5	80	Enviro sampler used	139
	-trace very fine gravel, stiff, low plasticity, moist	SPLIT SPOON	6	100	Grain Size Analysis Gravel: 20% Sand: 12% SIlt: 40% Clay: 28%	138
6	SILT, some sand, some clay, trace gravel (#50), stiff, non-plastic, grey, moist to wet	SPLIT SPOON	7	88	Enviro sampler used	
			8	0	Grain Size Analysis Gravel: 2% Sand: 20% Silt: 59% Clay: 19% Atterberg: Non-plastic refusal with Enviro sampler refusal with split spoon	137
7	BEDROCK	GRAB	9			136
8						
9		GRAB	10			135
10						134
11		GRAB	11			133
	End of Hole at 11.3 m					
12						132
13						131
14						130
15						129

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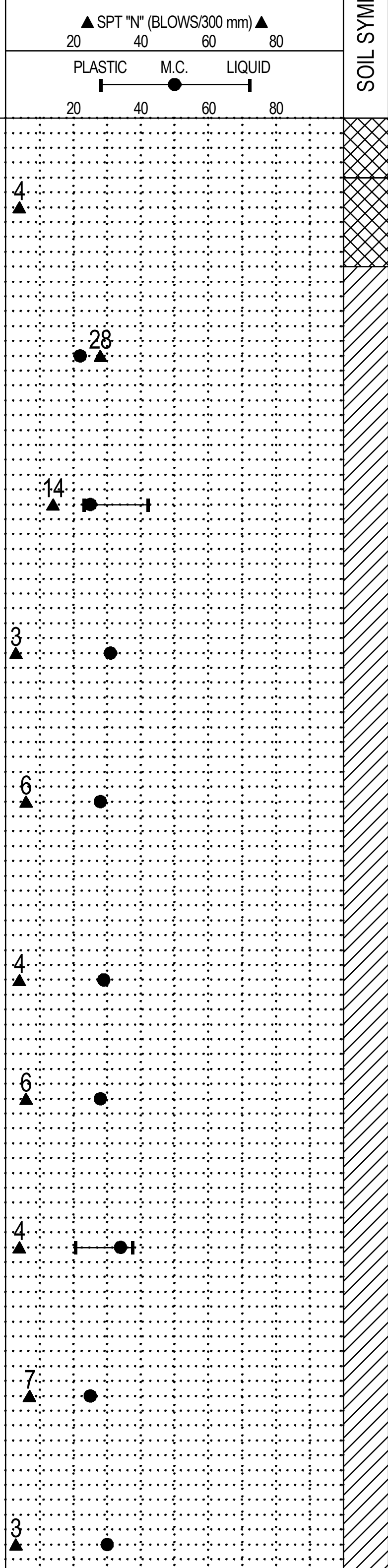
LOGGED BY: GM	COMPLETION DEPTH: 11.3 m
ENTERED BY: BP	COMPLETION DATE: 7/17/06

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH05-1**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80/Odex; wet rotary; HQ3 Coring	NORTHING: 5976642.49 EASTING: 517813.25	ELEVATION: 130.8 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN



DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0	GRAVEL, sandy, trace fines, coarse grained, compact to dense, brown, moist to wet (fill).				
1	SILT AND SAND, some gravel, loose, brown/black, contains ~50% wood and peat (FILL and topsoil)	Split spoon	NR		130
2	CLAY, trace sand, trace fine gravel, very stiff to hard, intermediate plasticity, laminated and fissured, brown (grey on fissures), moist	Split spoon	1		129
3					128
4	-becomes very stiff to stiff	Split spoon	2	Atterberg Limit Plastic 23% Liquid 42%	127
5	-becomes firm, grey, no sand and gravel	Split spoon	3		126
6					125
7	-becomes soft to firm, wet	Split spoon	4		124
8					123
9		Split spoon	5		122
10		Split spoon	6	-sampler sunk 75mm under rod weight	121
11		Split spoon	7	-sampler sunk 100mm under rod weight Atterberg Limit Plastic 21% Liquid 37%	120
12					119
13	-becomes soft	Split spoon	8		118
14	-trace gravel (dropstones)	Split spoon	9		117
15					116

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LOGGED BY: SK	COMPLETION DEPTH: 18.9 m
ENTERED BY: MO	COMPLETION DATE: 10/13/05

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH05-1**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80/Odex; wet rotary; HQ3 Coring	NORTHING: 5976642.49 EASTING: 517813.25	ELEVATION: 130.8 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m)	▲SPT "N" (BLOWS/300 mm)▲ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
15			CLAY, trace sand, trace fine gravel, very stiff to hard, intermediate plasticity, laminated and fissured, brown (grey on fissures), moist *(continued)*				115
16			BEDROCK, gneiss	CORE RETURN	10		
				CORE RETURN	11		114
17							
				CORE RETURN	12		113
18							
				CORE RETURN	13		112
19			End of hole at 18.92m Backfilled to surface with bentonite chips				
20							111
21							110
22							109
23							108
24							107
25							106
26							105
27							104
28							103
29							102
30							101

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CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH05-2**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80/Odex; wet rotary; HQ3 Coring	NORTHING: 5977330.46 EASTING: 517970.23	ELEVATION: 146 m

SAMPLE TYPE: TUBE, NO RECOVERY, SPLIT SPOON, GRAB, MUD RETURN, CORE RETURN

DEPTH (m)	▲SPT "N" (BLOWS/300 mm)▲ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0		BOULDERS, coarse, angular, sand and gravel, some fines, compact, brown, wet (FILL)				
1		SILT, sand and gravel, loose, low plastic, brown/black, wood and peat (25%), wet (FILL)				145
2		CLAY, very stiff, low to intermediate plasticity, laminated and fissured, brown, (grey on fissures), moist				144
	22		Split spoon	1	Atterberg Limit Plastic 22% Liquid 39%	
3						143
4	15	-becomes grey/dark brown	Split spoon	2		142
5						141
	19	-becomes firm to stiff, wet, few visible fissures	Split spoon	3	Atterberg Limit Plastic 19% Liquid 34%	
6						140
7		-some sand and gravel	Split spoon	4	SPT Refusal at 6.86m	139
		BEDROCK, gneiss	Core return			
8			Core return	5		138
		-sulphide mineralization in schistose zone at 8.5m to 9.0m depth				
9			Core return	6		137
10						136
		End of hole at 10.21m Backfilled to surface with bentonite chips				
11						135
12						134
13						133
14						132
15						

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	ENTERED BY: MO	COMPLETION DATE: 10/14/05

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH05-3**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80/Odex; wet rotary; HQ3 Coring	NORTHING: 5977375.72 EASTING: 517356.33	ELEVATION: 121.6 m

SAMPLE TYPE: TUBE, NO RECOVERY, SPLIT SPOON, GRAB, MUD RETURN, CORE RETURN

DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0 – 2.1		PEAT, wood, sand, silt and gravel, mixture, loose, brown/black, wet (sidecast road FILL and topsoil)				121.6
2.1 – 5.2		BEDROCK, gneiss. Includes banded quartz intrusions	CORE RETURN	1		
			CORE RETURN	2		
5.2		End of hole at 5.2m Backfilled to surface with bentonite chips				

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

Elevation scale: 121, 120, 119, 118, 117, 116, 115, 114, 113, 112, 111, 110, 109, 108, 107

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CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH05-4**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80/Odex; wet rotary; HQ3 Coring	NORTHING: 5977240.83 EASTING: 518399.85	ELEVATION: 109.6 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80

PLASTIC M.C. LIQUID 20 40 60 80

DEPTH (m)	SPT / M.C.	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0		GRAVEL AND SAND (coarse), few cobbles, angular, compact to dense, brown, moist, (FILL)				
		SILT, some woody debris and mixed organics (25%), firm to soft, brown, wet (FILL)				109
1		CLAY, trace fine sand in partings, very stiff, low to intermediate plasticity, laminated and fissured, brown (grey on fissures), moist				108
2.6	26		Split spoon	1	Atterberg Limit Plastic 24% Liquid 42%	107
4.1	26		Split spoon	2		106
4.5		-becomes silty, dark brown				105
5.4		-becomes grey, soft, wet				
5.6	3		Split spoon	3	Atterberg Limit Plastic 20% Liquid 34%	104
6		-some fine sand				103
6.7		SAND AND GRAVEL, some fines, dense, brown, wet			-description below 6.7m from air-lifted cuttings and drill reaction	102
9.3		-boulder from 9.3m to 104m depth				100
11.3		End of hole at 11.3m Backfilled to surface with bentonite chips			-refusal at 11.3m depth	98

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	ENTERED BY: MO	COMPLETION DATE: 10/15/05

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH05-4B**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80/Odex; wet rotary; HQ3 Coring	NORTHING: 5977240.83 EASTING: 518399.85	ELEVATION: 109.6 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

▲SPT "N" (BLOWS/300 mm)▲ 20 40 60 80

DEPTH (m)	SPT "N"	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0 – 1.2			COARSE GRAVEL AND SAND, few cobbles (angular), compact to dense, brown, moist (FILL) -contains organics below 0.45m depth				109
1.2 – 6.7			CLAY, trace fine sand in partings, very stiff, intermediate plasticity, laminated and fissured, brown (grey on partings), moist -becomes soft below 5.0m depth				108 – 103
6.7 –			SAND AND GRAVEL, some fines, dense, brown, wet			-description below 6.7m from air-lifted cuttings and drill reaction	103
12	82			SPLIT SPOON	1	Sieve Anaylsis Gravel 39%, Sand 50%, Fines 11%	97
14.3			-sandy gravel with frequent cobbles	SPLIT SPOON	NR	-SPT Refusal at 14.32m, 50 for 64mm then refusal	95
15							

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CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH05-4B**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80/Odex; wet rotary; HQ3 Coring	NORTHING: 5977240.83 EASTING: 518399.85	ELEVATION: 109.6 m

SAMPLE TYPE: TUBE, NO RECOVERY, SPLIT SPOON, GRAB, MUD RETURN, CORE RETURN

DEPTH (m)	SPT "N" (BLOWS/300 mm) 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
15			SAND AND GRAVEL, some fines, dense, brown, wet *(continued)*				94
16.8			SAND, gravelly, trace fines, compact, brown, wet				93, 92
18	24			Split spoon	2	Sieve Anaylsis Gravel 8%, Sand 58%, Fines 34%	91, 90
20.4			BEDROCK, gneiss	Core return	3		89
21				Core return	4		88
21.8			End of hole at 21.8m Backfilled to surface with bentonite chips				87 … 80

Depth scale: 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

Elevation scale: 94, 93, 92, 91, 90, 89, 88, 87, 86, 85, 84, 83, 82, 81, 80

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH05-5**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80/Odex; wet rotary; HQ3 Coring	NORTHING: 5977597.7 EASTING: 518693.54	ELEVATION: 88.6 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80; PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0			GRAVEL, coarse (FILL)				
			CLAY, hard, low plastic, brown, fissured and laminated, contains occasional dropstones (grey on fissured), moist				88
1							87
2	27				1		86
3							
	46		-becomes dark brown, contains trace gravel (dropstones), stiff		2		85
4							84
5	21		-becomes grey, firm		3		83
6							82
	9				4	Atterberg Limit Plastic 19% Liquid 32%	
7							81
8			-wet				
			-coarse grained between 8.1m and 8.4m				
			CLAY, some sand, some gravel, stiff, low plastic, dark brown, moist to wet (TILL-LIKE)				80
9							79
10	35				5		
11							78
12							77
13	61				6		76
14							75
15							74

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CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH05-5**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80/Odex; wet rotary; HQ3 Coring	NORTHING: 5977597.7 EASTING: 518693.54	ELEVATION: 88.6 m

SAMPLE TYPE: TUBE; NO RECOVERY; SPLIT SPOON; GRAB; MUD RETURN; CORE RETURN

SPT "N" (BLOWS/300 mm) 20 40 60 80; PLASTIC M.C. LIQUID 20 40 60 80

DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
15	CLAY, some sand, some gravel, stiff, low plastic, dark brown, moist to wet (TILL-LIKE) *(continued)*				73
15.7	GRAVEL, coarse and cobbles, dense (possible fractured bedrock)	SPLIT SPOON	NR	-SPT Refusal at 15.7m, 50 blows for 25mm, refusal on rock	72
17.2	BEDROCK, gneiss, quartz diorite (from rock chips)			-drilled to prove bedrock with air rotary, open hole hammer from 17.2m to 20.3m	71, 70, 69
20.3	End of hole at 20.3m Backfilled to surface with bentonite chips				68 … 59

Depth scale: 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

Elevation scale: 73, 72, 71, 70, 69, 68, 67, 66, 65, 64, 63, 62, 61, 60, 59

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LOGGED BY: SK	COMPLETION DEPTH: 20.3 m
ENTERED BY: MO	COMPLETION DATE: 10/17/05

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	BOREHOLE NO: **DH05-6**
DRILLER: Geotech Drilling Services Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
DRILL TYPE/METHOD: B-80/Odex; wet rotary; HQ3 Coring	NORTHING: 5977090.06 EASTING: 517908.31	ELEVATION: 143.5 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m)	▲ SPT "N" (BLOWS/300 mm) ▲ (20 40 60 80); PLASTIC — M.C. — LIQUID (20 40 60 80)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION
0		SAND AND GRAVEL, angular, dense, grey, moist (FILL)			
		WOOD (FILL)			
1		SILT AND SAND, organic, soft, brown/black, contains wood and peat, wet (topsoil or FILL)			
		CLAY, trace fine sand, hard, low to intermediate plasticity, brown, fissured and laminated (grey on fissures), moist			
2	33	-very stiff to hard	Split spoon	1	
4	21	-becomes stiff to very stiff, few fissures, trace gravel, (dropstone-rounded), dark brown	Split spoon	2	Atterberg Limit Plastic 21% Liquid 36%
5	14	-firm to soft, grey, wet	Split spoon	3	
7	19	-trace fine sand, trace gravel, firm	Split spoon	4	Atterberg Limit Plastic 18% Liquid 29%
8		BEDROCK, quartz diorite and gneiss, frequent sulphide inclusions	Core return	5	
			Core return	6	
			Core return	7	
12		End of hole at 11.8m Backfilled to surface with bentonite chips			

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

ELEVATION (m): 143, 142, 141, 140, 139, 138, 137, 136, 135, 134, 133, 132, 131, 130, 129

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LOGGED BY: SK	COMPLETION DEPTH: 11.8 m
ENTERED BY: MO	COMPLETION DATE: 10/18/05

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	TEST PIT NO: **TP05-01**
CONTRACTOR: JHW Construction Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
EXCAVATION METHOD: John Deere 892EL3	NORTHING: 5977427 EASTING: 518633	ELEVATION: 96.5 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m)	◆ POCKET PEN (kPa) ◆ 100 200 300 400 / PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0			PEAT, contains roots, brown/black, moist to wet				
1			CLAY, low plasticity, laminated, few silt pockets, brown, contains rootlets and fissures, moist				96, 95
	● (M.C. ~22)			GRAB	1		
	● (M.C. ~21), ◆ (~250 kPa)			GRAB	2		
2			End of Test Pit at 1.8m Test Pit walls did not slough. No seepage.			BEDROCK encountered at 1.8m	94
3–10							93–87

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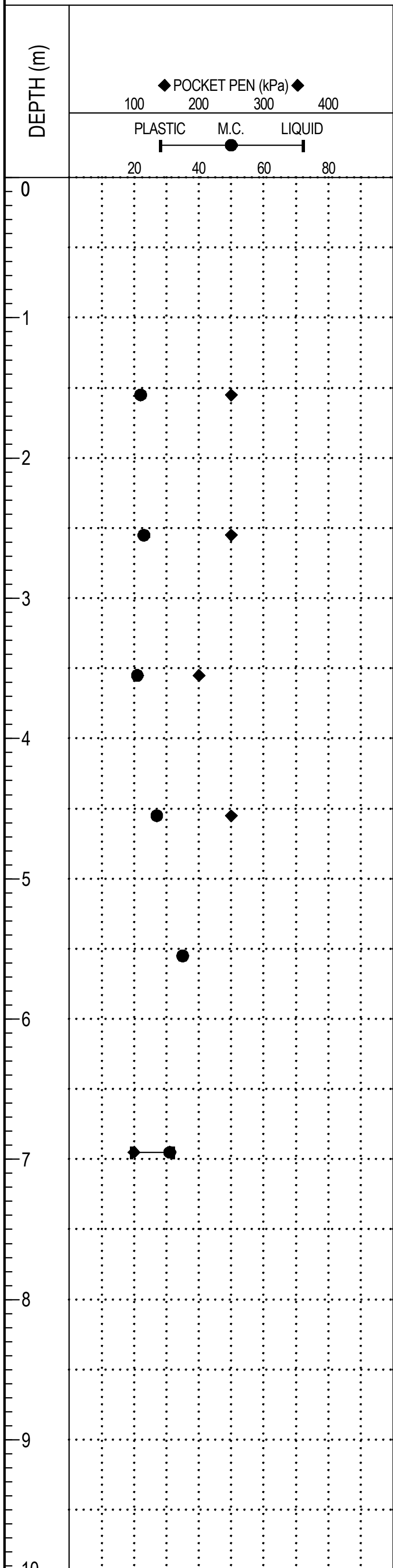
	ENTERED BY: SR	COMPLETION DATE: 11/18/05

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	TEST PIT NO: **TP05-03**
CONTRACTOR: JHW Construction Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
EXCAVATION METHOD: John Deere 892EL3	NORTHING: 5977411 EASTING: 518154	ELEVATION: 130.5 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN



DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0	SHOT ROCK (FILL) 300mm maximum diameter				130
1	PEAT, woody, brown, contains roots, moist				
	CLAY, intermediate plasticity, few silt layers, laminated, firm to stiff, light brown, moist to wet	GRAB	1		129
2		GRAB	2		128
3		GRAB	3		127
4	-becomes light grey at 3.8m depth				
	-wet below 4.5m depth	GRAB	4		126
5		GRAB	5		125
6					124
7		GRAB	6	Atterberg Limits Liquid Limit: 32% Plastic Limit: 19% No BEDROCK encountered	
	End of Test Pit at 7.1m Test Pit walls did not slough. No seepage observed.				123
8					122
9					121
10					

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	ENTERED BY: SR	COMPLETION DATE: 11/18/05

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	TEST PIT NO: **TP05-04**
CONTRACTOR: JHW Construction Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
EXCAVATION METHOD: John Deere 892EL3	NORTHING: 5976885 EASTING: 517879	ELEVATION: 154.5 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0		PEAT, woody, black, contains roots, moist				154
1		BEDROCK			BEDROCK encountered at 0.9m	
		End of Test Pit at 1.0m Test Pit walls did not slough. No seepage observed.				153
2						152
3						151
4						150
5						149
6						148
7						147
8						146
9						145
10						

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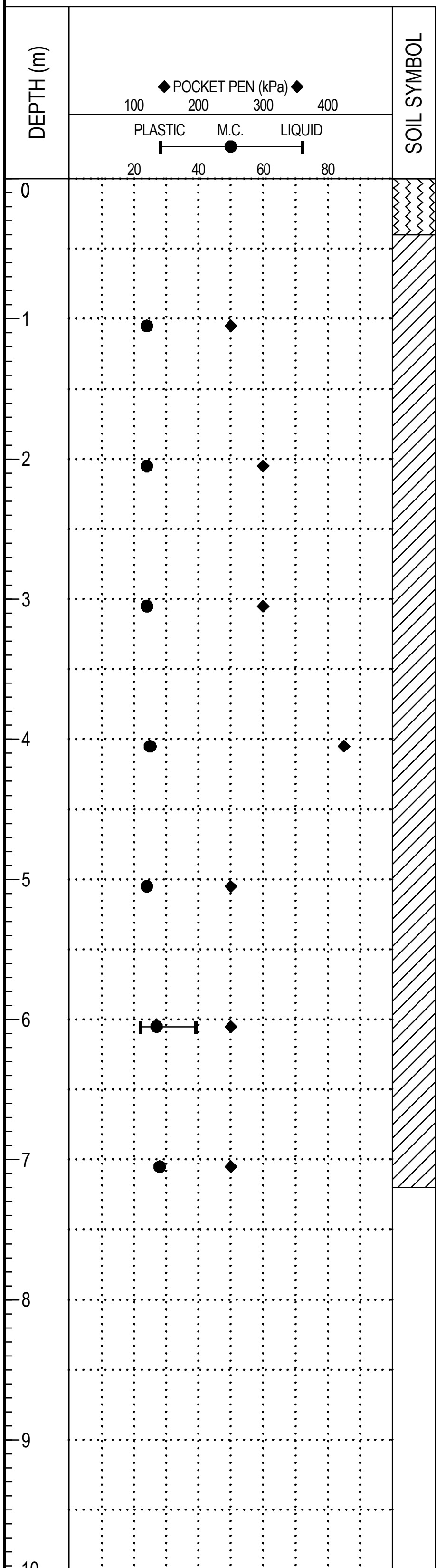
LOGGED BY: BH	COMPLETION DEPTH: 1.0 m
ENTERED BY: SR	COMPLETION DATE: 11/16/05

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	TEST PIT NO: **TP05-05**
CONTRACTOR: JHW Construction Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
EXCAVATION METHOD: John Deere 892EL3	NORTHING: 5976608 EASTING: 517578	ELEVATION: 122 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN



SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
PEAT, brown/black, contains roots, moist				
CLAY, intermediate plasticity, stiff to very stiff, nuggetty near surface, light grey, moist				
	GRAB	1		121
	GRAB	2		120
-more silty, blocky, stiff, light grey	GRAB	3		119
	GRAB	4		118
-becomes massive, moist to wet				
	GRAB	5		117
	GRAB	6	Atterberg Limits Liquid Limit: 39% Plastic Limit: 22%	116
	GRAB	7		115
End of Test Pit at 7.2m Test Pit walls did not slough. No seepage observed.			No BEDROCK encountered	
				114
				113

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LOGGED BY: BH	COMPLETION DEPTH: 7.2 m
ENTERED BY: SR	COMPLETION DATE: 11/18/05

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	TEST PIT NO: **TP05-06**
CONTRACTOR: JHW Construction Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
EXCAVATION METHOD: John Deere 892EL3	NORTHING: 5977407 EASTING: 517724	ELEVATION: 143 m

SAMPLE TYPE: TUBE / NO RECOVERY / SPLIT SPOON / GRAB / MUD RETURN / CORE RETURN

POCKET PEN (kPa): 100 200 300 400
PLASTIC M.C. LIQUID: 20 40 60 80

DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0	PEAT, woody, black, contains roots, moist				143
2	SAND, silty, fine grained, laminated, compact, light brown, damp to moist -structure interbedded with silt lenses to 2.8m depth (seen at sidewall) -moderate seepage into pit at 2.4m depth				141
3		GRAB	1		140
3.9		GRAB	2	Atterberg Limits Liquid Limit: 33% Plastic Limit: 20%	
4.2	SAND, some gravel, silty, compact to dense, rounded/subrounded, light grey, moist -silt laminations from 4.2m to 7.0m depth				
4.9		GRAB	3		
5.3		GRAB	4	Sieve Analysis Gravel: 19% Sand: 62% Fines: 19%	
6	-some moderate sloughing at 6.0m depth				137
7	-more dense gravel at 7.0m depth				136
7.5	End of Test Pit at 7.5m Test Pit walls sloughed at 6.0m. Seepage at 2.4m.	GRAB	5	Possible BEDROCK at 7.5m	

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Elevation scale: 142, 141, 140, 139, 138, 137, 136, 135, 134.

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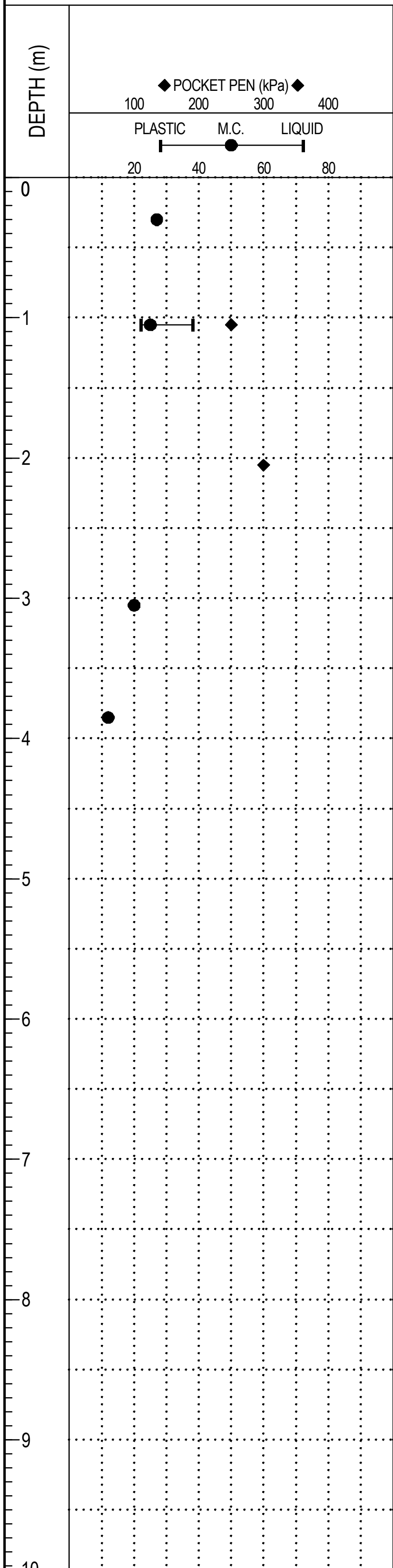
LOGGED BY: BH	COMPLETION DEPTH: 7.5 m
ENTERED BY: SR	COMPLETION DATE: 11/16/05

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	TEST PIT NO: **TP05-08**
CONTRACTOR: JHW Construction Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
EXCAVATION METHOD: John Deere 892EL3	NORTHING: 5977923 EASTING: 517639	ELEVATION: 150.5 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN



Depth (m)	Soil Description	Sample Type	Sample No	Additional Information
0	ORGANICS, forest floor, roots, organic odor, brown, moist			
	CLAY, intermediate plasticity, stiff, brown, contains rootlets, moist			
1	-becomes firm, light grey below 1.1m	GRAB	1	Atterberg Limits Liquid Limit: 38% Plastic Limit: 22%
2	-some seepage, some sloughing at 2.3m	GRAB	2	
	SAND, silty, laminated, greyish brown, moist to wet			
3		GRAB	3	
	SAND AND GRAVEL (TILL-LIKE), gravel sizes to 50mm, light brown, moist	GRAB	4	Sieve Analysis Gravel: 12% Sand: 53% Fines: 35% BEDROCK encountered at 4.2m
	End of Test Pit at 4.2m Test Pit walls sloughed at 2.3m. Seepage at 2.3m.			

ELEVATION (m): 150, 149, 148, 147, 146, 145, 144, 143, 142, 141

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Burnaby, BC, CANADA, V5C 5A9

LOGGED BY: BH	COMPLETION DEPTH: 4.2 m
ENTERED BY: SR	COMPLETION DATE: 11/15/05

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	TEST PIT NO: **TP05-09**
CONTRACTOR: JHW Construction Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
EXCAVATION METHOD: John Deere 892EL3	NORTHING: 5977970 EASTING: 517981	ELEVATION: 183 m

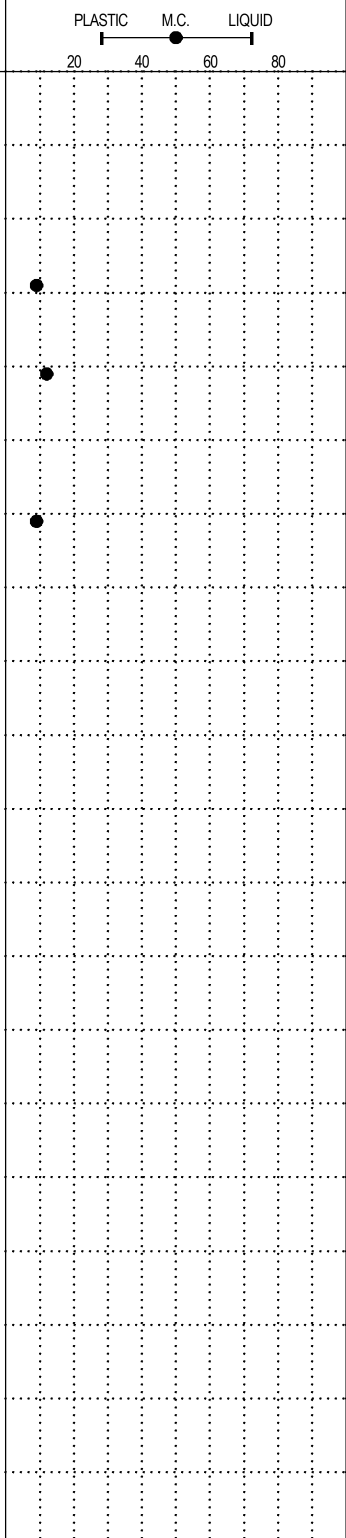
SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0		ORGANICS, roots, fiberous, brown/black -water flowing from treeline side into test pit at 1.1m depth				
1						182
		CLAY, intermediate plasticity, stiff, grey, moist				
		BEDROCK			BEDROCK encountered at 1.3m	
		End of Test Pit at 1.4m Test Pit walls did not slough. Lots of water flowing.				
2						181
3						180
4						179
5						178
6						177
7						176
8						175
9						174
10						

amec	AMEC Earth & Environmental 2227 Douglas Road Burnaby, BC, CANADA, V5C 5A9	LOGGED BY: BH ENTERED BY: SR
		COMPLETION DEPTH: 1.4 m COMPLETION DATE: 11/16/05

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	TEST PIT NO: **TP05-10**
CONTRACTOR: JHW Construction Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
EXCAVATION METHOD: John Deere 892EL3	NORTHING: 5978164 EASTING: 518027	ELEVATION: 175 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN



DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0	PEAT, brown/black, contains roots, moist to wet				175
1.4	SAND, silty, some gravel, oxidized, compact, grey, moist	GRAB	1		
2.0	-very stiff to hard from 2.0m to 2.8m depth	GRAB	2		
2.8	-becomes hard at 2.8m depth	GRAB	3	Sieve Analysis Gravel: 25% Sand: 44% Fines: 31% BEDROCK encountered at 3.2m	
3.2	BEDROCK End of Test Pit at 3.3m Test Pit walls did not slough. No seepage observed.				

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Elevation scale: 174, 173, 172, 171, 170, 169, 168, 167, 166.

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2227 Douglas Road
Burnaby, BC, CANADA, V5C 5A9

LOGGED BY: BH	COMPLETION DEPTH: 3.3 m
ENTERED BY: SR	COMPLETION DATE: 11/16/05

CLIENT: Northern Gateway Pipelines Inc.	PROJECT: Preliminary Geotechnical Report	TEST PIT NO: **TP05-11**
CONTRACTOR: JHW Construction Ltd.	Proposed Kitimat Terminal	PROJECT NO: EG0926008.4200
EXCAVATION METHOD: John Deere 892EL3	NORTHING: 5978305 EASTING: 517885	ELEVATION: 141 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

PLASTIC — M.C. — LIQUID (20, 40, 60, 80)

DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	ADDITIONAL INFORMATION	ELEVATION (m)
0		PEAT, black/brown, contains roots, moist				
		SAND, silty, some gravel, dense, brown, moist				
1			GRAB	1		140
2		-few cobbles, becomes, grey				139
			GRAB	2		
3			GRAB	3		138
		BEDROCK	GRAB	4	Sieve Analysis Gravel: 15% Sand: 48% Fines: 37% BEDROCK encountered at 3.8m	
4						137
		End of Test Pit at 4.4m Test Pit walls did not slough. No seepage observed.				
5						136
6						135
7						134
8						133
9						132
10						

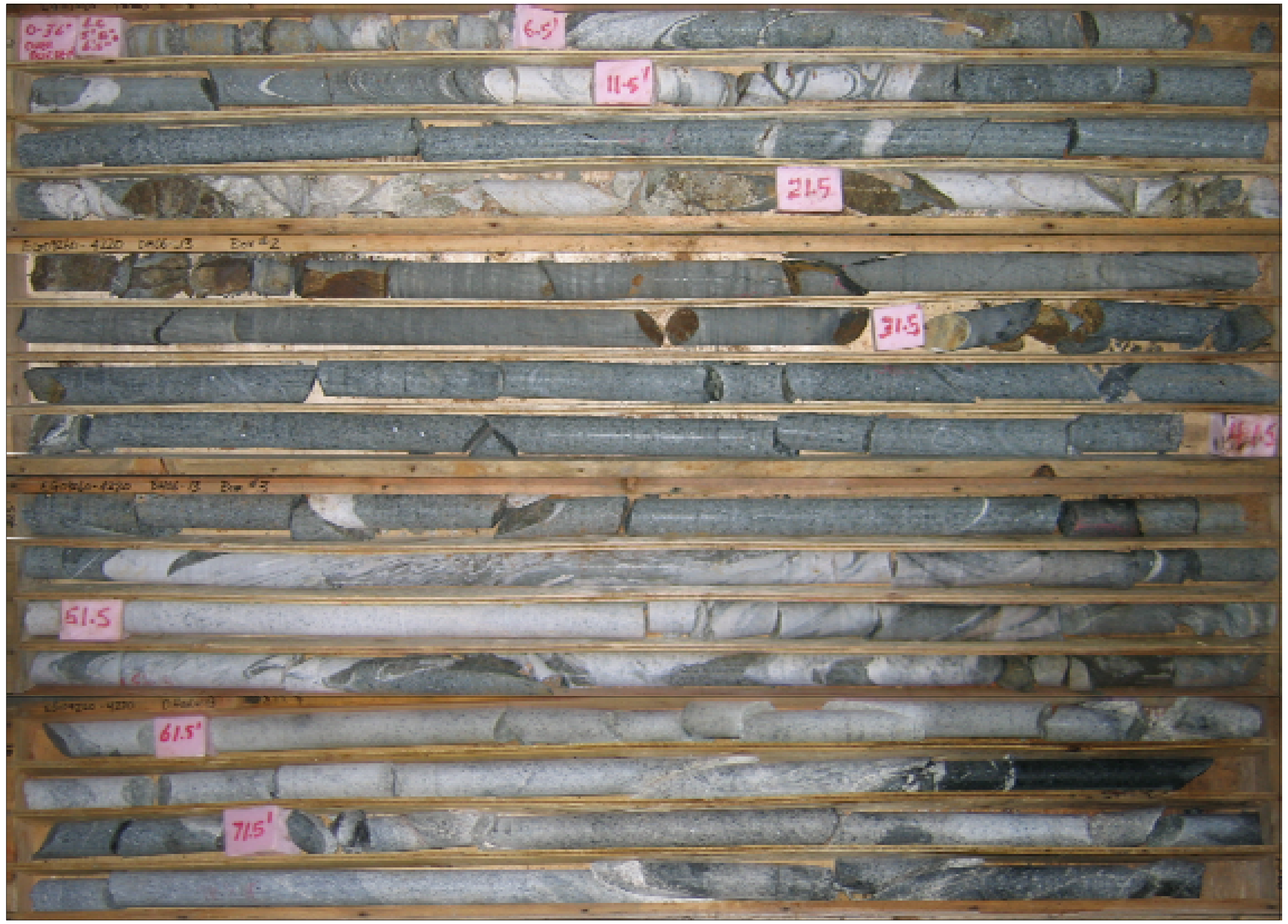
BH WITH MC LAB TESTPITS.GPJ AMEC PG.GDT 5/19/09

amec

AMEC Earth & Environmental
2227 Douglas Road
Burnaby, BC, CANADA, V5C 5A9

LOGGED BY: BH	COMPLETION DEPTH: 4.4 m
ENTERED BY: SR	COMPLETION DATE: 11/15/05

DH06-13
1.1m - 24.5m (3.5' - 80.5')



DH06-13
24.5m - 46.2m (80.5' - 151.5')

CLIENT: ENBRIDGE NORTHERN GATEWAY PIPELINES	DWN BY: I.Macleod CHK'D BY: S.Kelly	TITLE: DRILL CORE PHOTOS DH06-13	DATE: SEPTEMBER 2009 PROJECT NO: EG0926008.4200
AMEC Earth & Environmental 2227 Douglas Road Burnaby, BC, CANADA, V5C 5A9 Tel. (604) 294-3811 Fax (604) 294-4664	DATUM: N/A PROJECTION: N/A SCALE: NOT TO SCALE	PROJECT: PRELIMINARY GEOTECHNICAL REPORT ON PROPOSED KITIMAT TERMINAL	REV. NO.: B FIGURE No. CORE 1 of 7

P:\PROJECTS\Other Offices\EG-Edmonton\EG09260 - Enbridge Gateway\4200 - Kitimat Terminal\Reports_Deliverables\Rev R\Appendix D\GateEG0926008.4200-CORE.dwg - 06-13 - Sep. 10, 2009 10:37am - michael.m.wong

This drawing was originally produced in colour.

DH06-14
0.0m - 25.1m (0.0' - 82.5')

DH06-14
25.1m - 43.6m (82.5' - 143.0')

CLIENT: ENBRIDGE NORTHERN	DWN BY: I.Macleod	TITLE: DRILL CORE PHOTOS DH06-14	DATE: SEPTEMBER 2009
	CHK'D BY: S.Kelly		PROJECT NO: EG0926008.4200
AMEC Earth & Environmental, 3456 Opie Crescent, Prince George, BC, CANADA V2N 2P9, Tel. (250) 564-3243, Fax (250) 562-7045	DATUM: N/A	PROJECT: PRELIMINARY GEOTECHNICAL REPORT ON PROPOSED KITIMAT TERMINAL	REV. NO.: B
amec	PROJECTION: N/A		FIGURE No. CORE 2 of 7
	SCALE: NOT TO SCALE		

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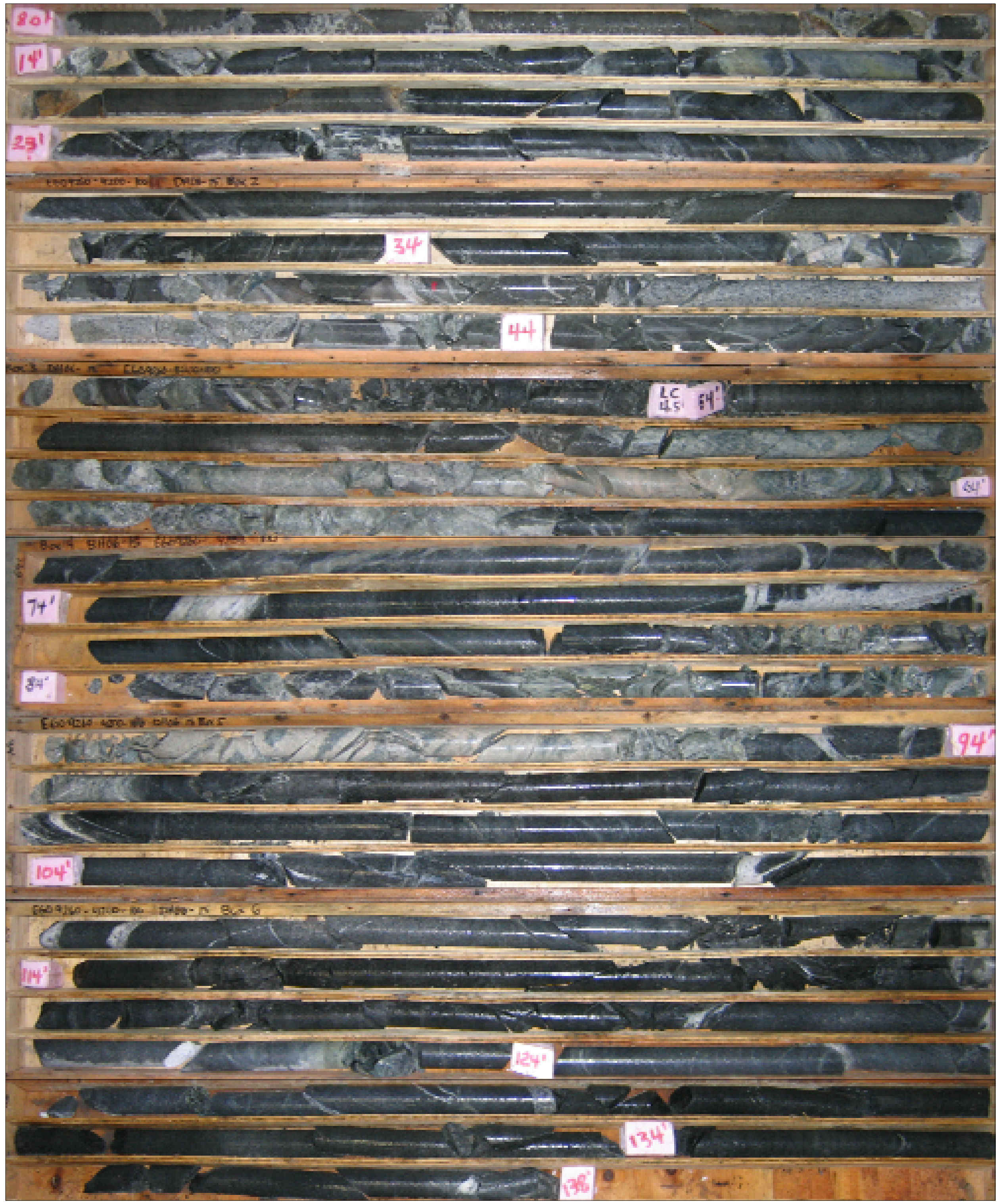
This drawing was originally produced in colour.

DH06-15

2.4m - 42.1m (8.0' - 138.0')



DH06-16

0.0m - 33.5m (0.0' - 110.0')

CLIENT: ENBRIDGE NORTHERN GATEWAY PIPELINES	DWN BY: I.Macleod	TITLE: DRILL CORE PHOTOS DH06-15 AND BH06-16	DATE: SEPTEMBER 2009
	CHK'D BY: S.Kelly		PROJECT NO: EG0926008.4200
AMEC Earth & Environmental 3456 Opie Crescent Prince George, BC, CANADA V2N 2P9 Tel. (250) 564-3243 Fax (250) 562-7045	DATUM: N/A	PROJECT: PRELIMINARY GEOTECHNICAL REPORT ON PROPOSED KITIMAT TERMINAL	REV. NO.: B
amec	PROJECTION: N/A		FIGURE No.
	SCALE: NOT TO SCALE		CORE 3 of 7

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This drawing was originally produced in colour.

DH06-17
1.2m - 30.0m (4.0' - 98.5')

DH06-17
30.0m - 46.8m (98.5' - 153.5')

CLIENT: ENBRIDGE NORTHERN GATEWAY PIPELINES	DWN BY: I.Macleod	TITLE: DRILL CORE PHOTOS DH06-17	DATE: SEPTEMBER 2009
	CHK'D BY: S.Kelly		PROJECT NO: EG0926008.4200
AMEC Earth & Environmental 3456 Opie Crescent Prince George, BC, CANADA V2N 2P9 Tel. (250) 564-3243 Fax (250) 562-7045	DATUM: N/A	PROJECT: PRELIMINARY GEOTECHNICAL REPORT ON PROPOSED KITIMAT TERMINAL	REV. NO.: B
amec	PROJECTION: N/A		FIGURE No. CORE 4 of 7
	SCALE: NOT TO SCALE		

This drawing was originally produced in colour.

DH06-18
1.5m - 18.9m (5.0' - 62.0')

DH06-18
18.9m - 40.8m (62.0' - 134.0')

CLIENT:		DWN BY: I.Macleod	TITLE	DRILL CORE PHOTOS DH06-18	DATE: SEPTEMBER 2009
		CHK'D BY: S.Kelly			PROJECT NO: EG0926008.4200
AMEC Earth & Environmental 3456 Opie Crescent Prince George, BC, CANADA V2N 2P9 Tel. (250) 564-3243 Fax (250) 562-7045	amec	DATUM: N/A	PROJECT	PRELIMINARY GEOTECHNICAL REPORT ON PROPOSED KITIMAT TERMINAL	REV. NO.: B
		PROJECTION: N/A			FIGURE No. CORE 5 of 7
		SCALE: NOT TO SCALE			

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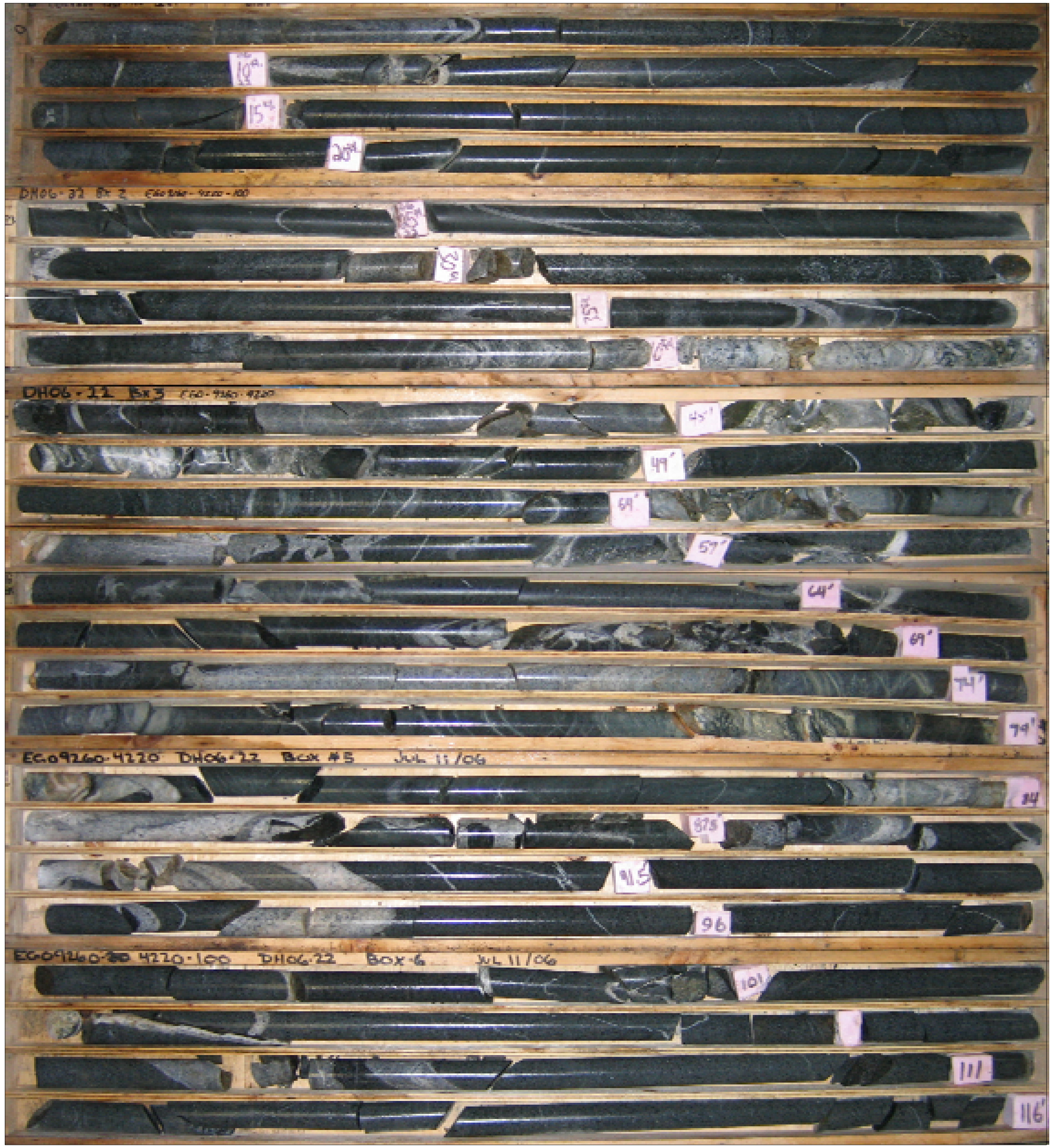
This drawing was originally produced in colour.

DH06-22
0.0m - 35.4m (0.0' - 116.0')



DH06-22
35.4m - 69.9m (116.0' - 229.5')

CLIENT: ENBRIDGE NORTHERN GATEWAY PIPELINES	DWN BY: I.Macleod	TITLE	DRILL CORE PHOTOS DH06-22 PAGE 1 OF 2	DATE: SEPTEMBER 2009
	CHK'D BY: S.Kelly			PROJECT NO: EG0926008.4200
AMEC Earth & Environmental 3456 Opie Crescent Prince George, BC, CANADA V2N 2P9 Tel. (250) 564-3243 Fax (250) 562-7045	DATUM: N/A	PROJECT	PRELIMINARY GEOTECHNICAL REPORT ON PROPOSED KITIMAT TERMINAL	REV. NO.: B
amec	PROJECTION: N/A			FIGURE No. CORE 6 of 7
	SCALE: NOT TO SCALE			

This drawing was originally produced in colour.

DH06-22

69.9m - 97.2m (229.5' - 319.0')

CLIENT: ENBRIDGE NORTHERN GATEWAY PIPELINES	DWN BY: I.Macleod	TITLE: DRILL CORE PHOTOS DH06-22 PAGE 2 OF 2	DATE: SEPTEMBER 2009
	CHK'D BY: S.Kelly		PROJECT NO: EG0926008.4200
AMEC Earth & Environmental 3456 Opie Crescent Prince George, BC, CANADA V2N 2P9 Tel. (250) 564-3243 Fax (250) 562-7045	DATUM: N/A	PROJECT: PRELIMINARY GEOTECHNICAL REPORT ON PROPOSED KITIMAT TERMINAL	REV. NO.: B
amec	PROJECTION: N/A		FIGURE No. CORE 7 of 7
	SCALE: NOT TO SCALE		

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This drawing was originally produced in colour.

Appendix CPTU
Cone Penetration Tests

CONETEC

Job No: 06-208
Client: AMEC
Project: Enbridge - Kitimat
Date: 07/11/06 - 07/14/06

CPT SUMMARY

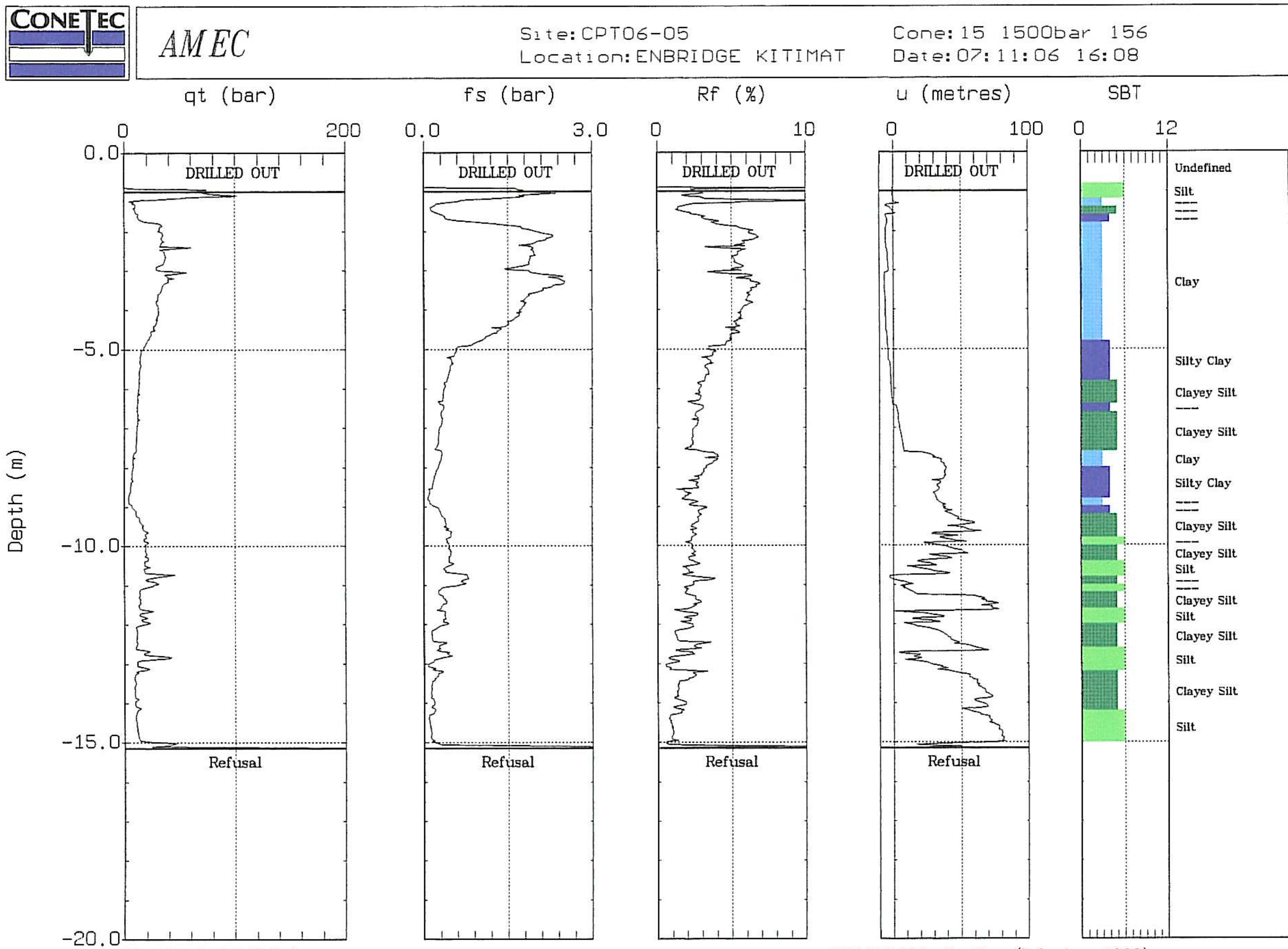
CPT Sounding	File Name	Date	Cone	Assumed Phreatic Surface (m)	Final Depth (m)
CPT06-05	208CP01	07/11/06	15 1500bar 156	5.0	15.150
CPT06-04	208CP02	07/12/06	15 1500bar 156	5.0	16.100
SCPT06-10	208CP03	07/13/06	15 375bar 199	6.0	13.675
SCPT06-04	208CP04	07/13/06	15 375bar 199	2.9	11.125
CPT06-07	208CP05	07/14/06	15 375bar 199	5.5	6.200
SCPT06-03	208CP06	07/14/06	15 375bar 199	5.5	24.450
SCPT06-08	208CP07	07/14/06	15 375bar 199	6.0	17.475

Note: Hydrostatic water table assumed for interpretation tables

AMEC

Site: CPT06-05
Location: ENBRIDGE KITIMAT

Cone: 15 1500bar 156
Date: 07:11:06 16:08



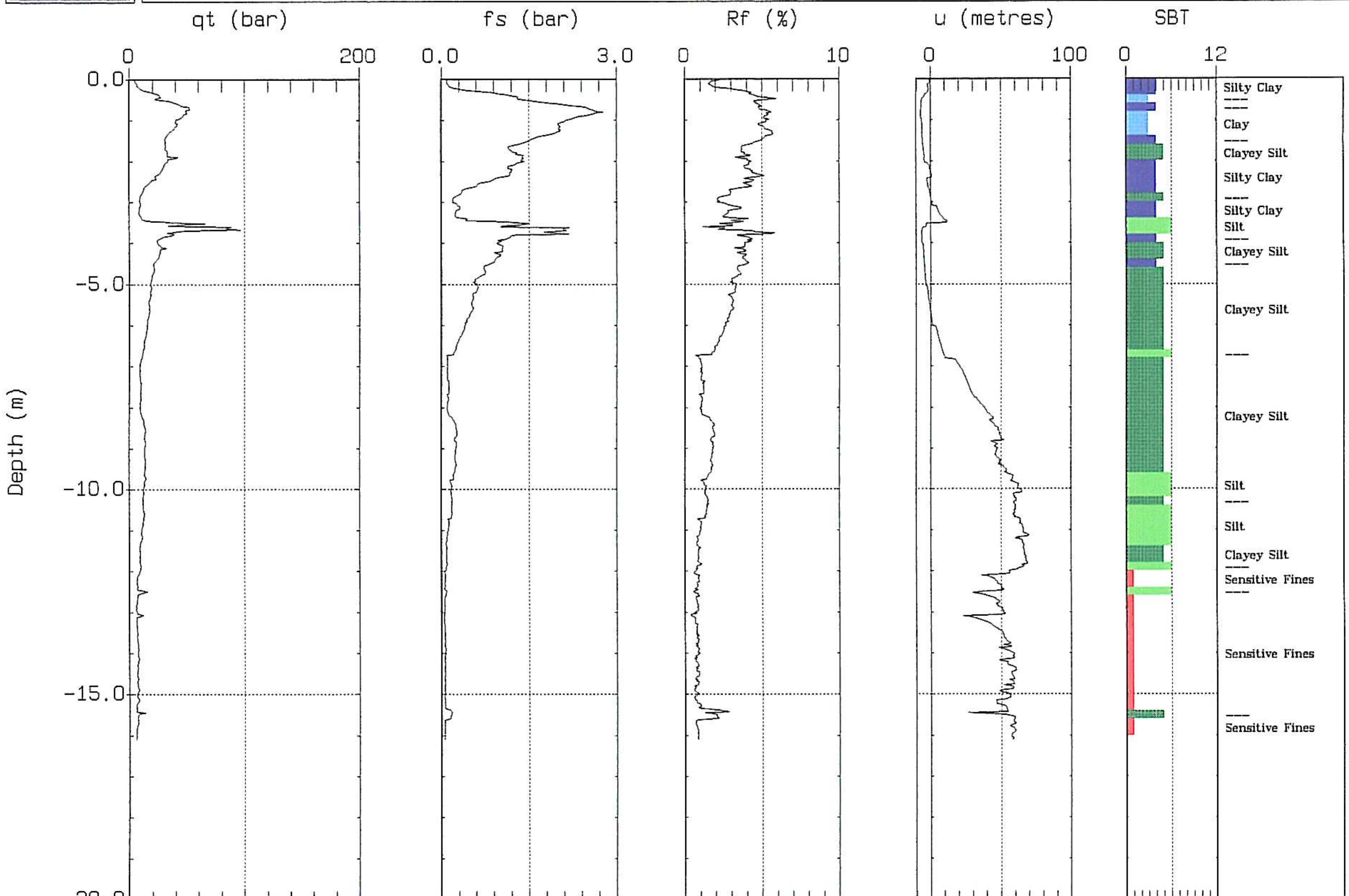
Max. Depth: 15.15 (m)
Depth Inc.: 0.025 (m)

SBT: Soil Behavior Type (Robertson 1990)

AMEC

Site: CPT06-04
Location: ENBRIDGE KITIMAT

Cone: 15 1500bar 156
Date: 07:12:06 14:34



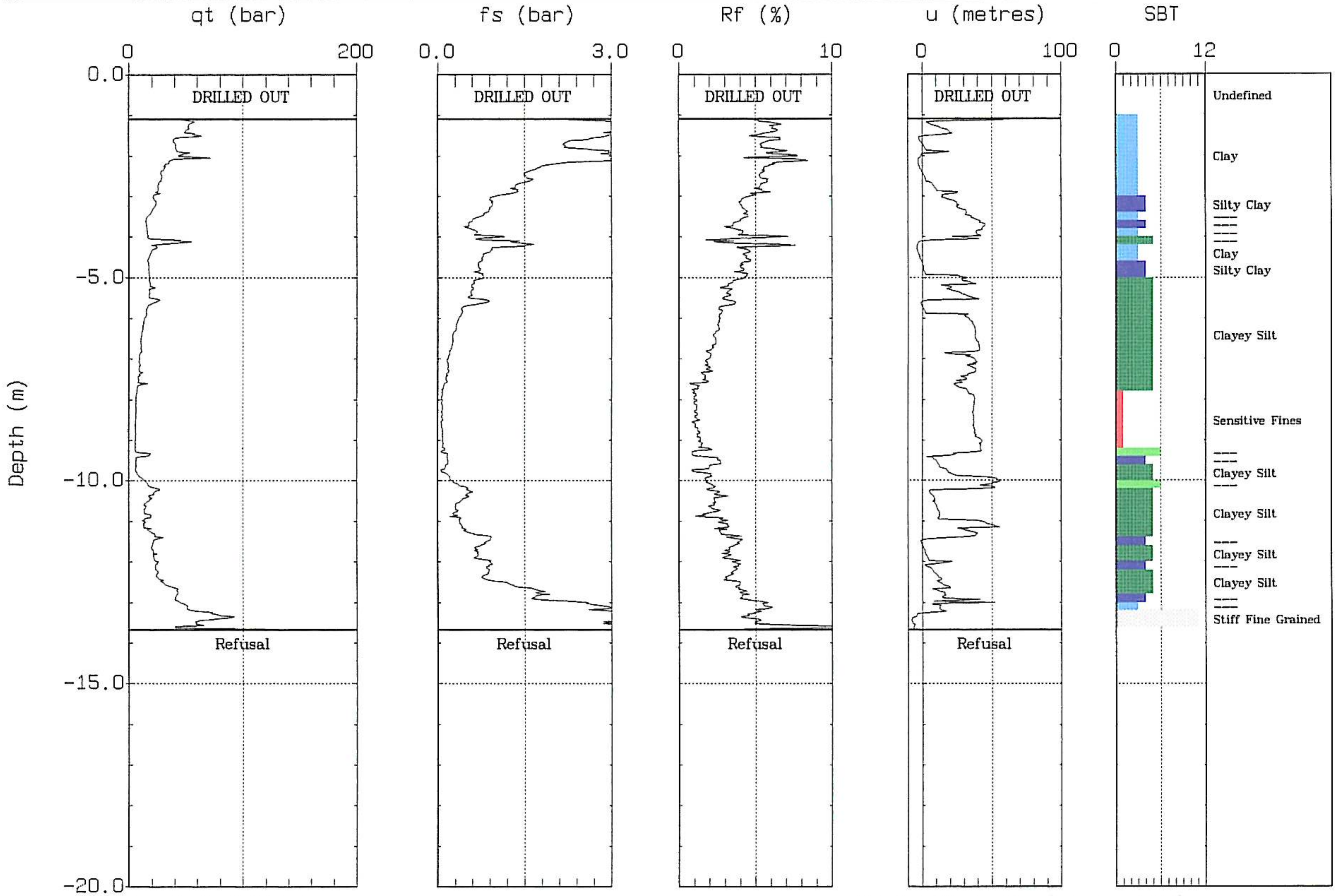
Max. Depth: 16.10 (m)
Depth Inc.: 0.025 (m)

SBT: Soil Behavior Type (Robertson 1990)

AMEC

Site: SCPT06-10
Location: ENBRIDGE KITIMAT

Cone: 15 375bar 199
Date: 07:13:06 10:14



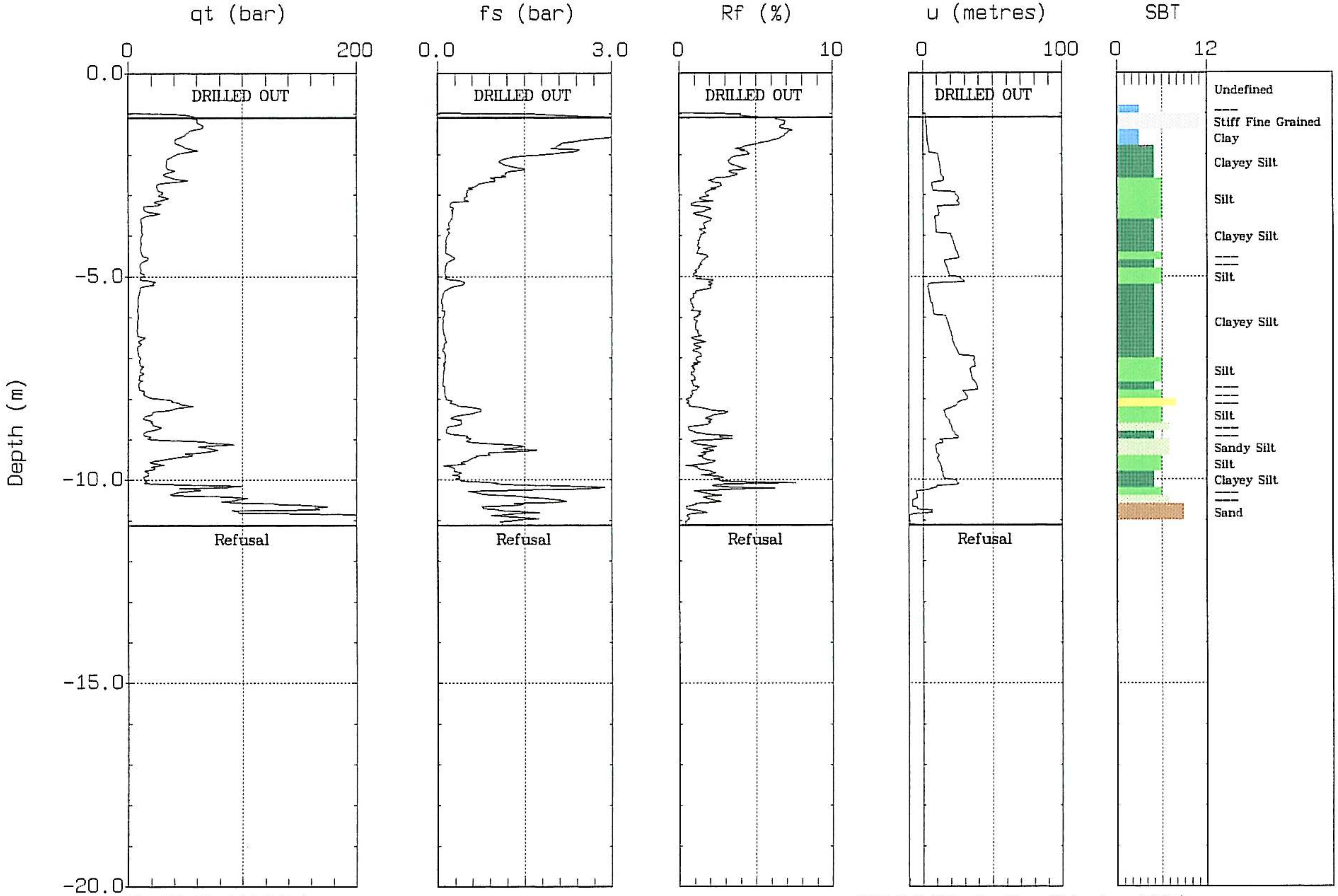
Max. Depth: 13.68 (m)
Depth Inc.: 0.025 (m)

SBT: Soil Behavior Type (Robertson 1990)

AMEC

Site: SCPT06-04
Location: ENBRIDGE KITIMAT

Cone: 15 375bar 199
Date: 07:13:06 15:09



Max. Depth: 11.12 (m)
Depth Inc.: 0.025 (m)

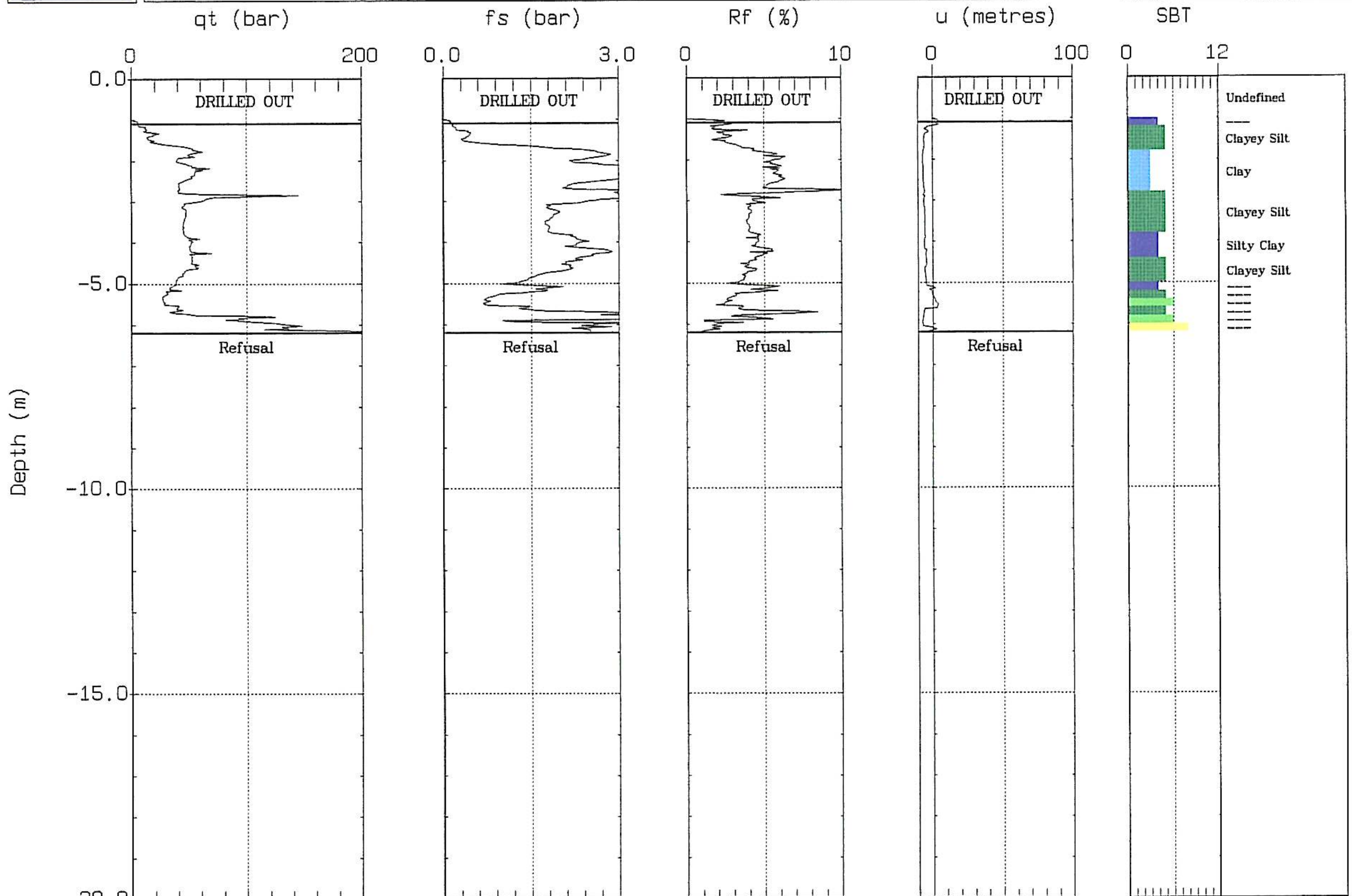
SBT: Soil Behavior Type (Robertson 1990)

CONETEC

AMEC

Site: CPT06-07
Location: ENBRIDGE KITIMAT

Cone: 15 375bar 199
Date: 07:14:06 09:16



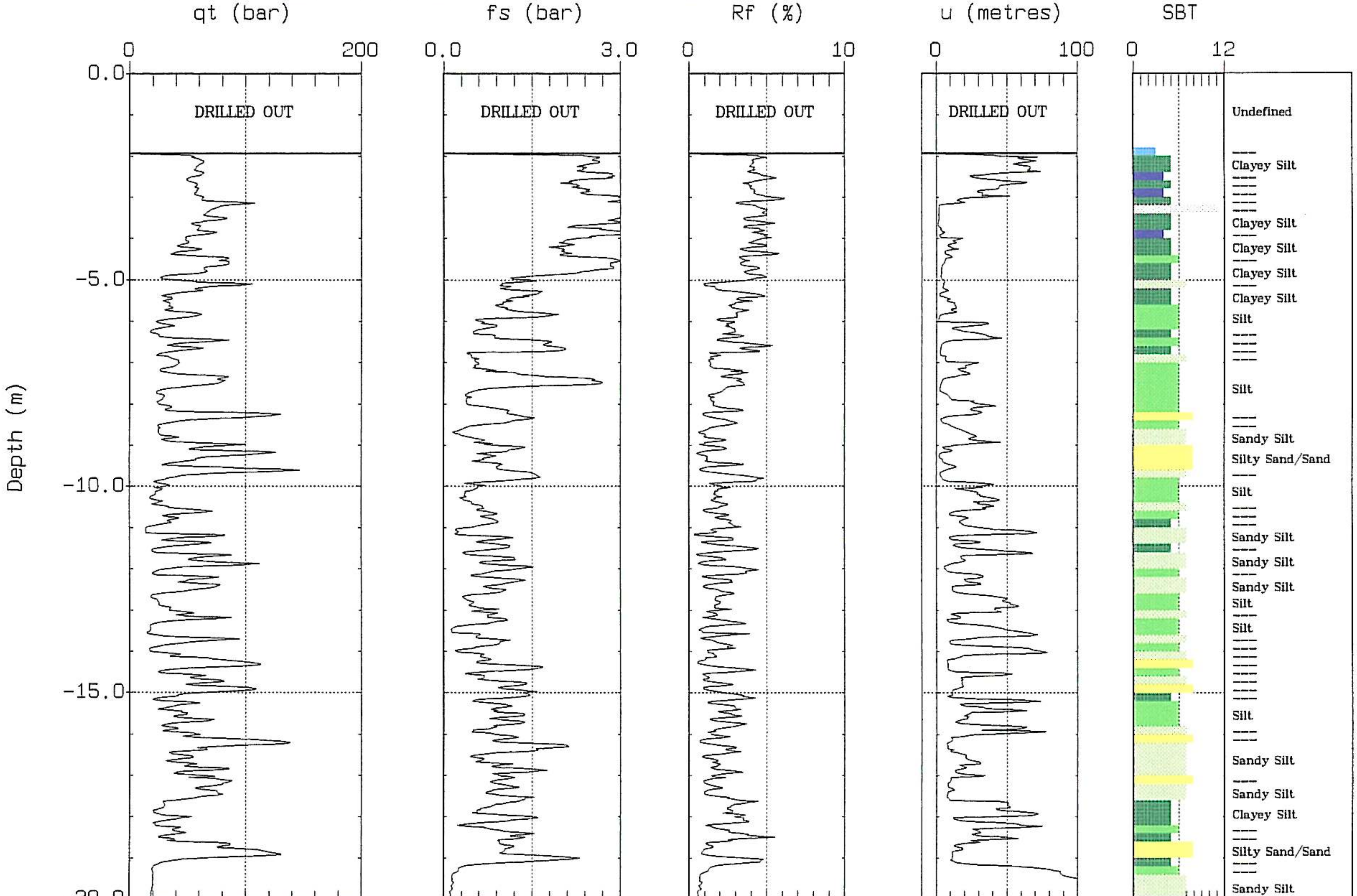
Max. Depth: 6.20 (m)
Depth Inc.: 0.025 (m)

SBT: Soil Behavior Type (Robertson 1990)

AMEC

Site: SCPT06-03
Location: ENBRIDGE KITIMAT

Cone: 15 375bar 199
Date: 07:14:06 14:07



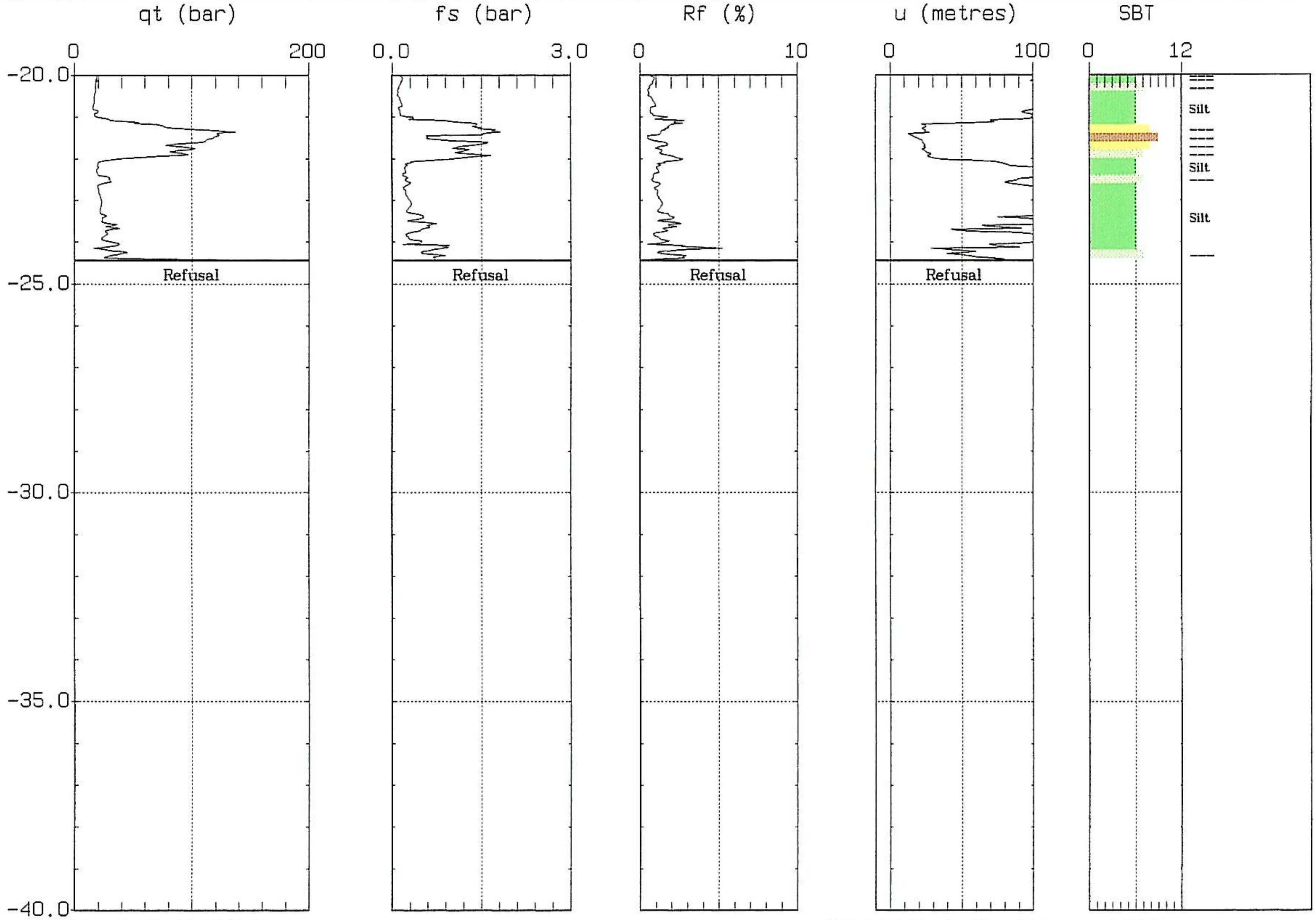
Max. Depth: 24.45 (m)
Depth Inc.: 0.025 (m)

SBT: Soil Behavior Type (Robertson 1990)

AMEC

Site: SCPT06-03
Location: ENBRIDGE KITIMAT

Cone: 15 375bar 199
Date: 07:14:06 14:07



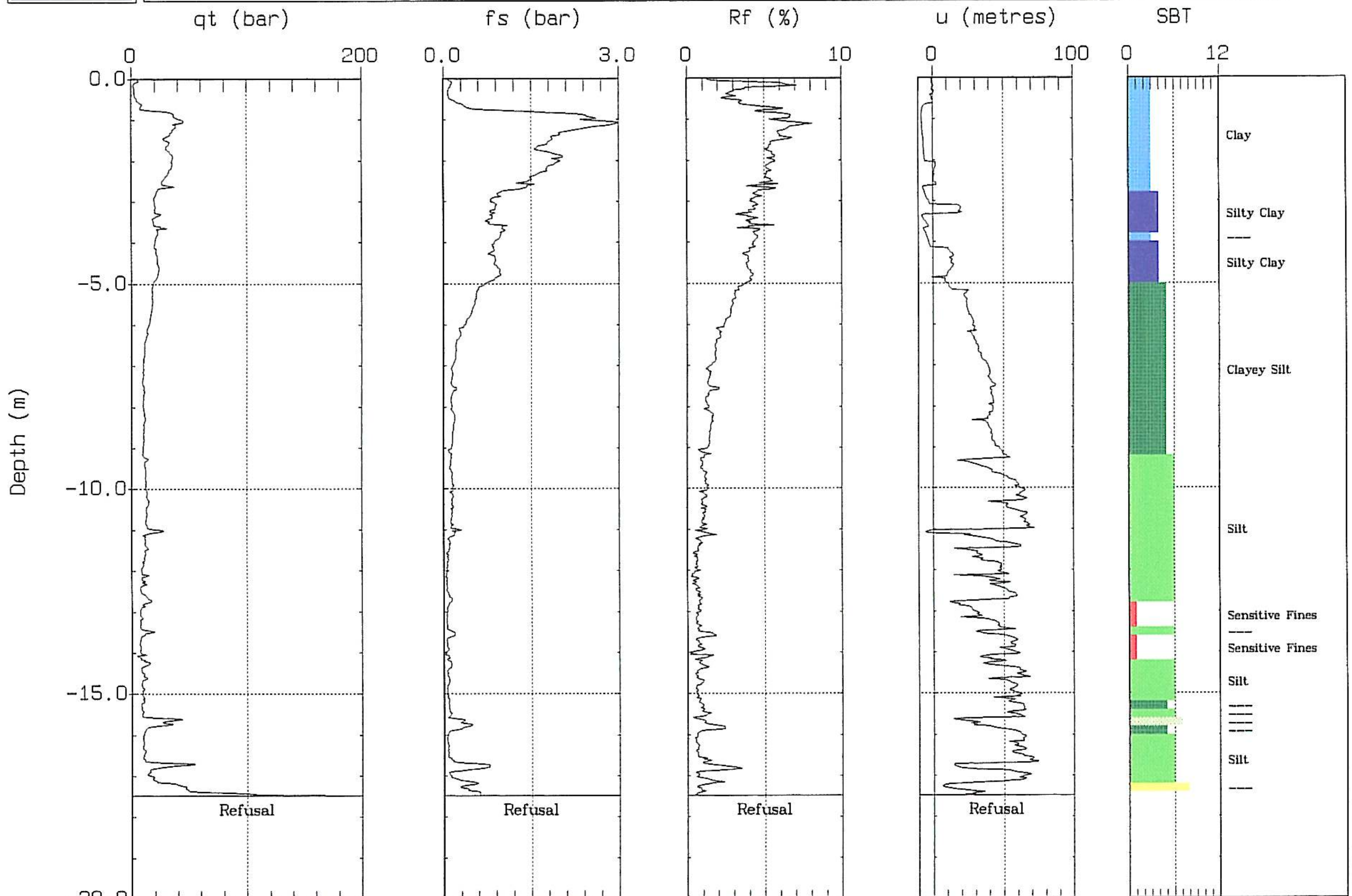
Max. Depth: 24.45 (m)
Depth Inc.: 0.025 (m)

SBT: Soil Behavior Type (Robertson 1990)

AMEC

Site: SCPT06-08
Location: ENBRIDGE KITIMAT

Cone: 15 375bar 199
Date: 07:14:06 17:34



Max. Depth: 17.48 (m)
Depth Inc.: 0.025 (m)

SBT: Soil Behavior Type (Robertson 1990)

Appendix PPD
Pore Pressure Dissipation Tests

CONETEC

Job No: 06-208
Client: AMEC
Project: Enbridge - Kitimat
Date: 07/11/06 - 07/14/06

PPD SUMMARY

CPT Sounding	Duration (s)	Test Depth (m)	Equilibrium Pore Pressure U_{eq} (m)	Calculated Phreatic Surface (m)*	Estimated Phreatic Surface (m)	t_{50} (s)**	c_h (cm^2/min)***
CPT06-04	4000	16.10	-	-	6.00	921	0.78
SCPT06-04	1930	10.73	7.80	2.93	-	-	-

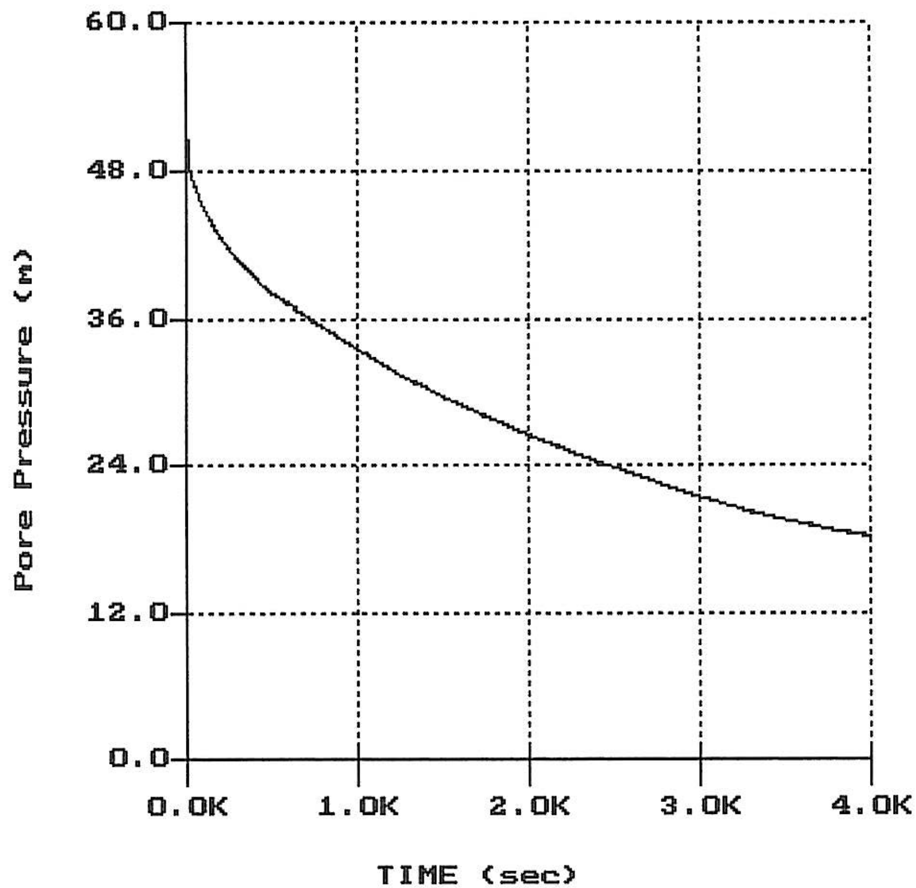
* Note: The calculated phreatic surface is based on equilibrium pore pressures and assumed hydrostatic conditions
** t_{50} is calculated based on U initial and assumed equilibrium pore pressure
***c_h calculated based on Robertson et al., 1992

AMEC

Hole:CPT06-04
Location:ENBRIDGE KITIMAT

Cone:15 1500bar 156
Date:07:12:06 14:34

PORE PRESSURE DISSIPATION RECORD



File: 208CP02.PPD
Depth (m): 16.10
(ft): 52.82
Duration : 4000.0s
U-min: 18.07 4000.0s
U-max: 58.22 0.0s

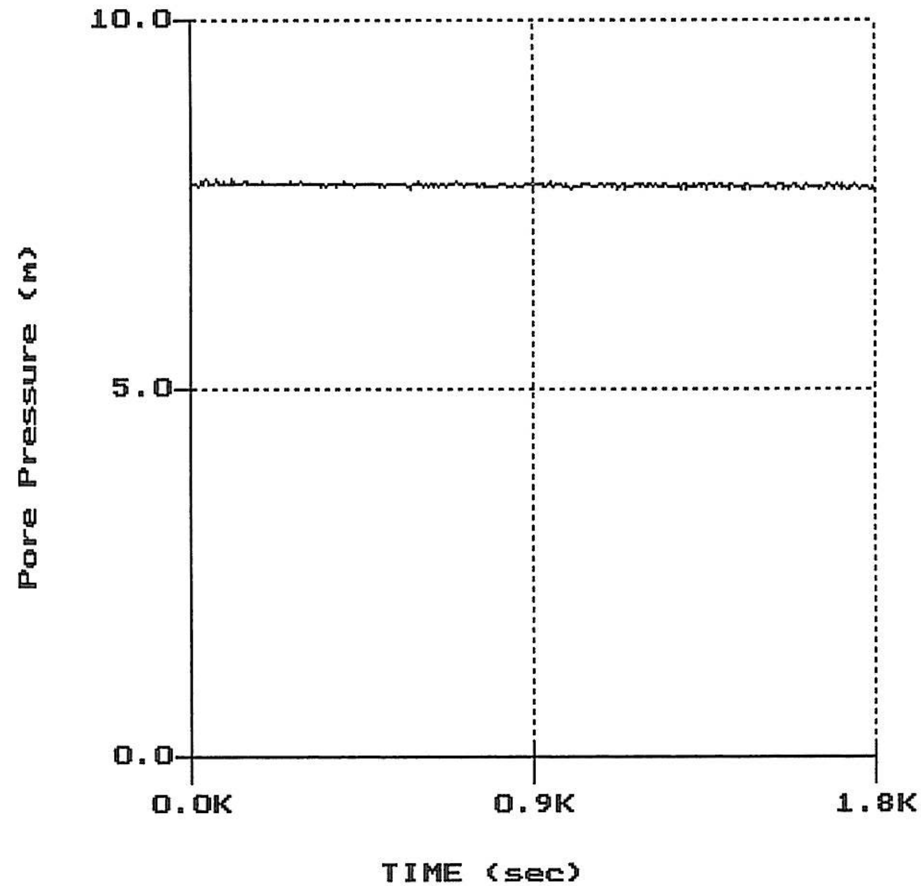
AMEC

Hole:SCPT06-04
Location:ENBRIDGE KITIMAT

Cone:15 375bar 199
Date:07:13:06 15:09

File: 208CP04.PPD
Depth (m): 10.73
(ft): 35.20
Duration : 1930.0s
U-min: 7.69 1860.0s
U-max: 9.00 1930.0s

PORE PRESSURE DISSIPATION RECORD



Appendix SCPTU
Seismic Cone Penetration Tests

CONETEC

Client:	AMEC
Project:	Enbridge Kitimat
Sounding:	SCPT 06-03
Date:	July 14, 2006

Seismic Source:	Beam
Source Offset (m):	0.10
Source Depth (m):	0.00
Geophone Offset (m):	0.20

SEISMIC

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Depth Interval (m)	Time Interval (ms)	Vs (m/s)	Mid Layer (m)
2.00	1.80	1.80				
2.95	2.75	2.75	0.95	4.07	233	2.28
3.97	3.77	3.77	1.02	3.87	263	3.26
5.12	4.92	4.92	1.15	4.41	261	4.34
6.00	5.80	5.80	0.88	3.73	236	5.36
6.97	6.77	6.77	0.97	4.68	207	6.28
7.90	7.70	7.70	0.93	4.41	211	7.23
9.02	8.82	8.82	1.12	4.28	262	8.26
10.02	9.82	9.82	1.00	4.62	217	9.32
11.05	10.85	10.85	1.03	4.34	237	10.34
12.12	11.92	11.92	1.07	5.16	207	11.38
13.05	12.85	12.85	0.93	3.67	254	12.38
14.07	13.87	13.87	1.02	4.82	212	13.36
15.05	14.85	14.85	0.98	4.13	237	14.36
16.05	15.85	15.85	1.00	4.10	244	15.35
17.02	16.82	16.82	0.97	4.30	226	16.33
18.00	17.80	17.80	0.98	3.63	270	17.31
19.02	18.82	18.82	1.02	3.76	271	18.31
20.10	19.90	19.90	1.08	4.57	237	19.36
21.15	20.95	20.95	1.05	3.76	279	20.42
22.17	21.97	21.97	1.02	4.03	253	21.46
23.10	22.90	22.90	0.93	3.09	301	22.44
24.12	23.92	23.92	1.02	3.16	323	23.41

CONETEC

Client:	AMEC
Project:	Enbridge Kitimat
Sounding:	SCPT 06-04
Date:	July 13, 2006

Seismic Source:	Beam
Source Offset (m):	0.10
Source Depth (m):	0.00
Geophone Offset (m):	0.20

SEISMIC

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Depth Interval (m)	Time Interval (ms)	Vs (m/s)	Mid Layer (m)
1.95	1.75	1.75				
2.90	2.70	2.70	0.95	4.43	214	2.23
3.92	3.72	3.72	1.02	4.33	236	3.21
4.97	4.77	4.77	1.05	4.83	217	4.24
5.92	5.72	5.72	0.95	4.63	205	5.24
6.92	6.72	6.72	1.00	4.88	205	6.22
7.77	7.57	7.57	0.85	4.18	203	7.14
8.97	8.77	8.77	1.20	4.88	246	8.17
9.97	9.77	9.77	1.00	3.83	261	9.27

Client:	AMEC	
Project:	Enbridge Kitimat	
Sounding:	SCPT 06-08	
Date:	July 14, 2006	

Seismic Source:	Beam
Source Offset (m):	0.10
Source Depth (m):	0.00
Geophone Offset (m):	0.20

SEISMIC

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Depth Interval (m)	Time Interval (ms)	Vs (m/s)	Mid Layer (m)
1.07	0.87	1.33				
2.02	1.82	2.08	0.75	5.03	149	1.34
3.07	2.87	3.04	0.96	5.64	171	2.34
4.12	3.92	4.05	1.01	5.03	200	3.39
5.15	4.95	5.05	1.00	4.49	224	4.43
6.15	5.95	6.03	0.98	5.09	193	5.45
7.12	6.92	6.99	0.96	4.92	195	6.43
8.12	7.92	7.98	0.99	5.25	189	7.42
9.12	8.92	8.98	0.99	5.43	183	8.42
10.15	9.95	10.00	1.02	5.68	180	9.43
11.10	10.90	10.95	0.95	4.50	210	10.42
12.07	11.87	11.91	0.97	4.41	219	11.38
13.12	12.92	12.96	1.05	4.75	220	12.39
14.05	13.85	13.89	0.93	4.58	203	13.38
15.07	14.87	14.90	1.02	4.50	226	14.36
16.15	15.95	15.98	1.08	4.66	231	15.41
17.15	16.95	16.98	1.00	4.41	226	16.45

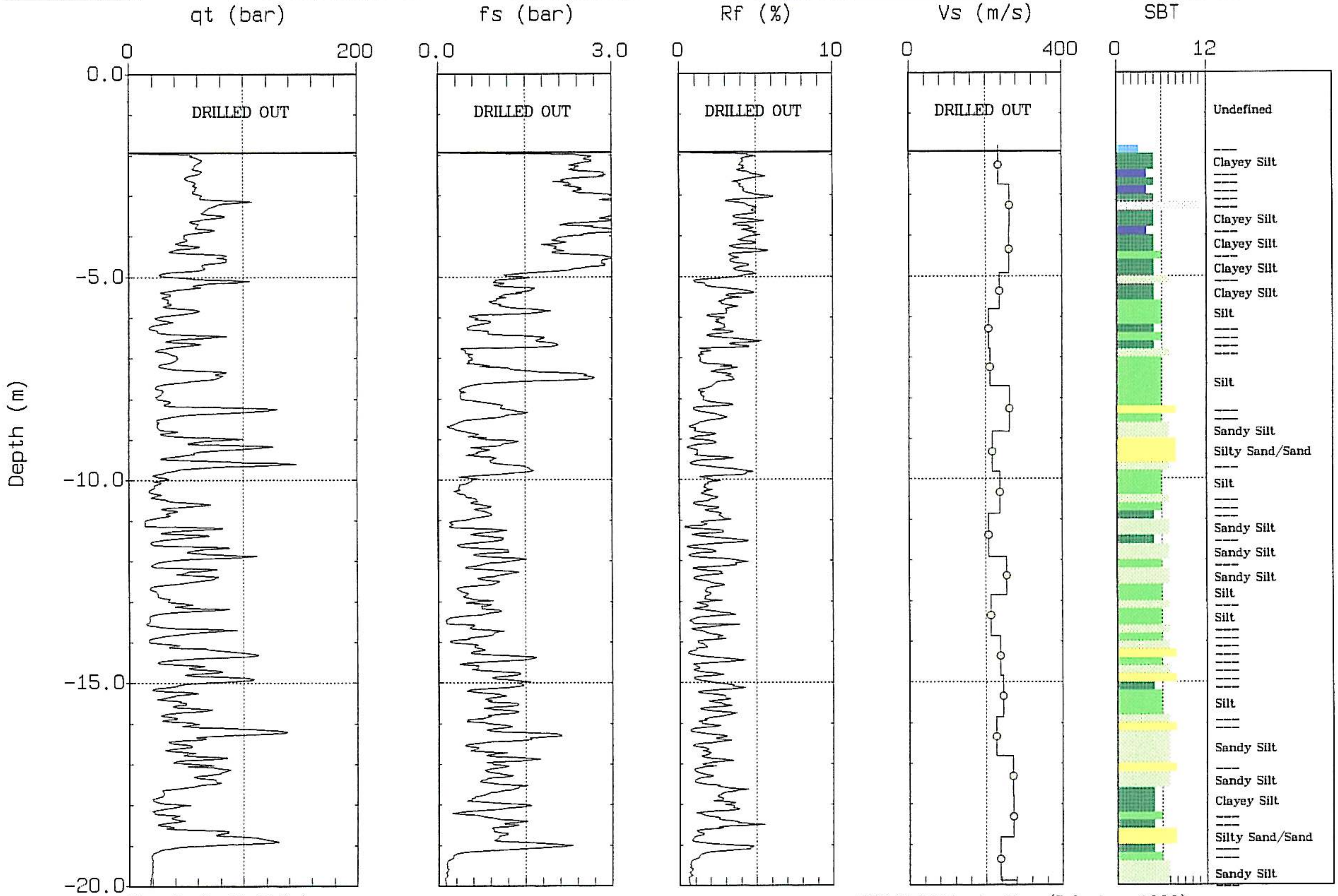
Client:	AMEC
Project:	Enbridge Kitimat
Sounding:	SCPT 06-10
Date:	July 13, 2006

Seismic Source:	Beam
Source Offset (m):	0.10
Source Depth (m):	0.00
Geophone Offset (m):	0.20

SEISMIC

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Depth Interval (m)	Time Interval (ms)	Vs (m/s)	Mid Layer (m)
1.87	1.67	1.95				
2.87	2.67	2.85	0.90	5.96	152	2.17
3.82	3.62	3.76	0.90	4.08	222	3.14
4.92	4.72	4.82	1.07	4.91	218	4.17
5.87	5.67	5.76	0.93	4.45	209	5.19
6.87	6.67	6.74	0.99	5.21	189	6.17
7.82	7.62	7.69	0.94	4.83	195	7.14
8.87	8.67	8.73	1.04	5.74	182	8.14
9.87	9.67	9.72	0.99	5.74	173	9.17
10.95	10.75	10.80	1.07	4.15	259	10.21
11.97	11.77	11.81	1.02	3.70	275	11.26
12.90	12.70	12.74	0.93	3.40	273	12.23
13.67	13.47	13.51	0.77	2.57	299	13.08

CONETEC	AMEC	Site: SCPT06-03 Location: ENBRIDGE KITIMAT	Cone: 15 375bar 199 Date: 07:14:06 14:07



Max. Depth: 24.45 (m)
Depth Inc.: 0.025 (m)

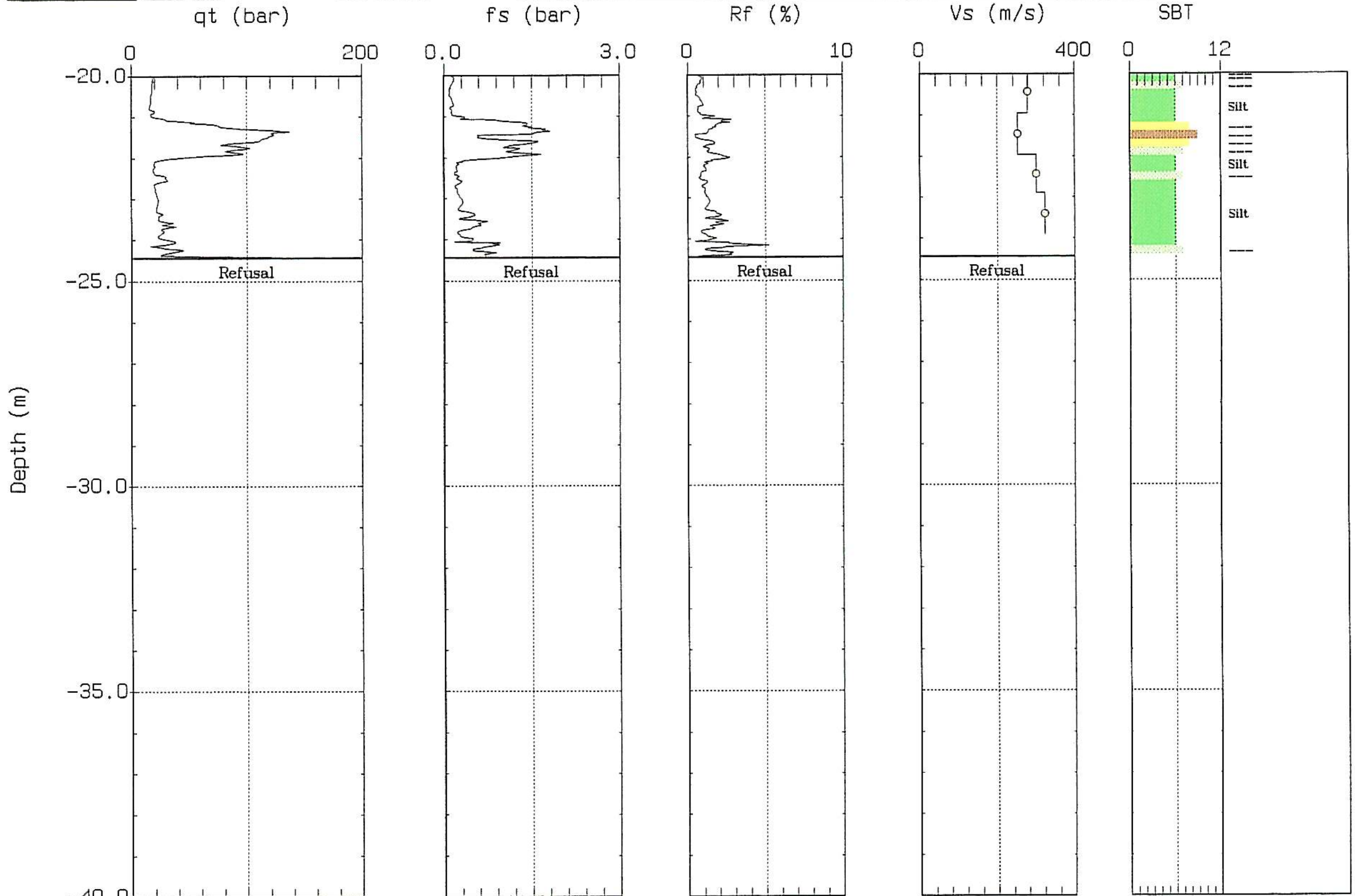
SBT: Soil Behavior Type (Robertson 1990)

CONETEC

AMEC

Site: SCPT06-03
Location: ENBRIDGE KITIMAT

Cone: 15 375bar 199
Date: 07:14:06 14:07



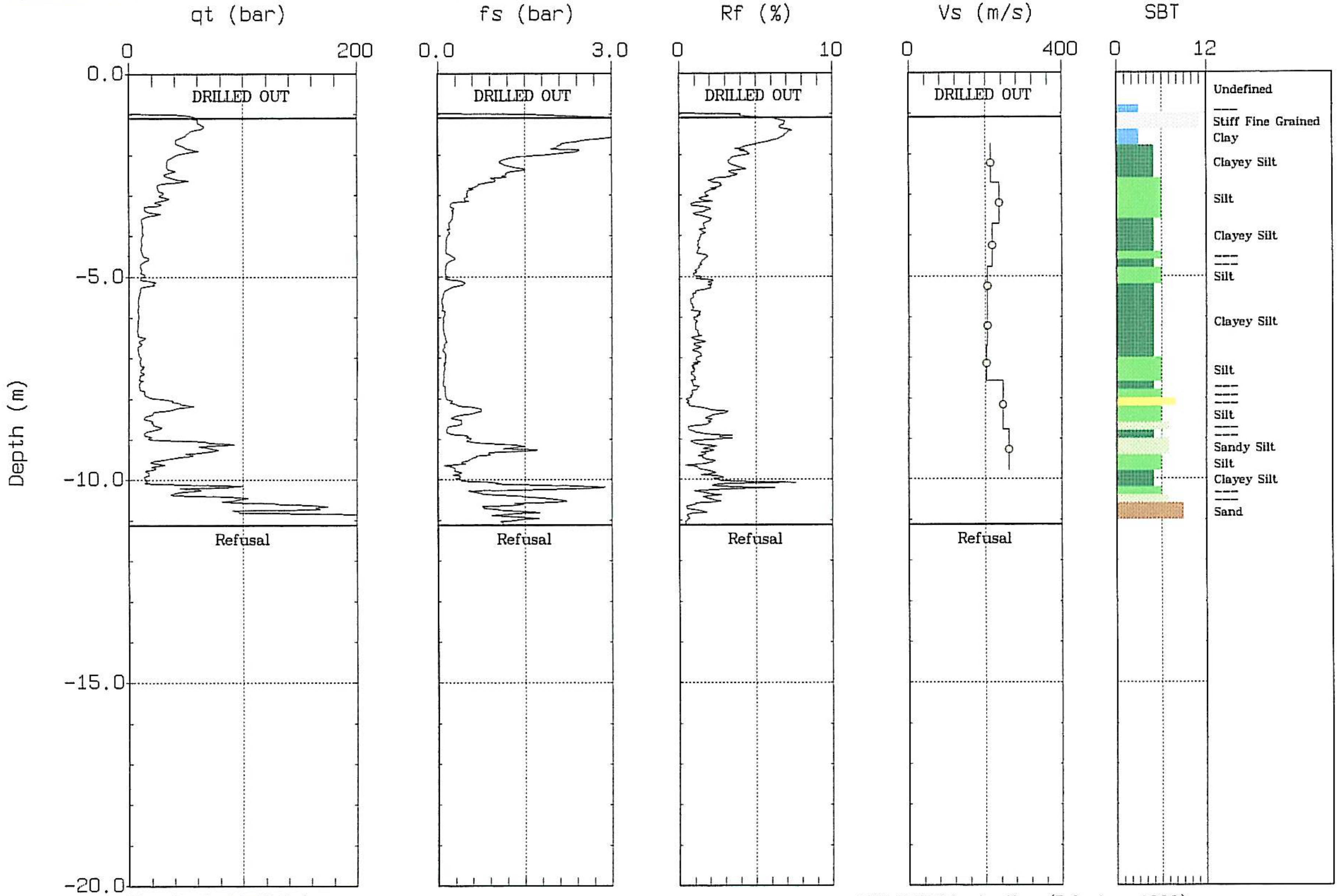
Max. Depth: 24.45 (m)
Depth Inc.: 0.025 (m)

SBT: Soil Behavior Type (Robertson 1990)

AMEC

Site: SCPT06-04
Location: ENBRIDGE KITIMAT

Cone: 15 375bar 199
Date: 07:13:06 15:09



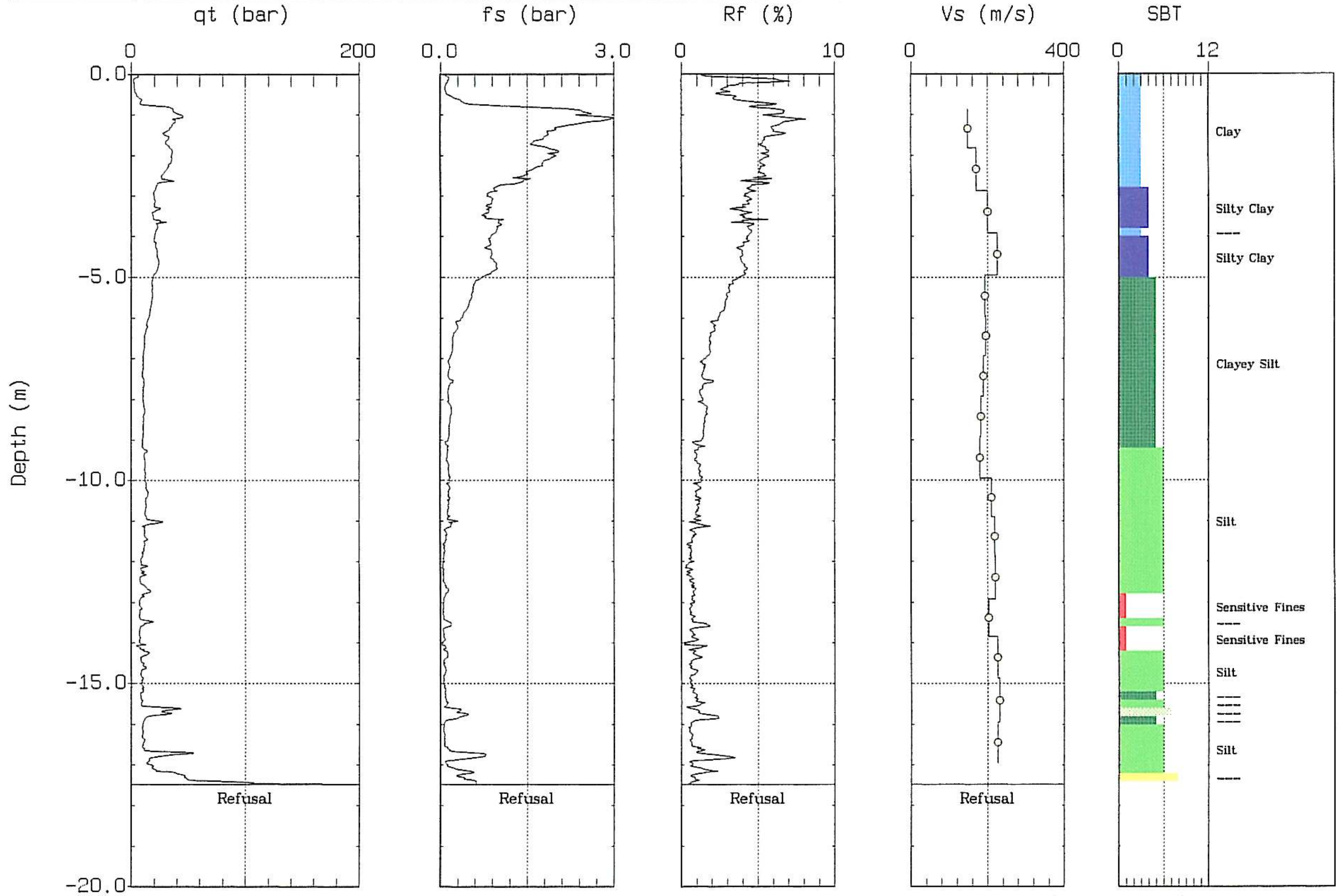
Max. Depth: 11.12 (m)
Depth Inc.: 0.025 (m)

SBT: Soil Behavior Type (Robertson 1990)

AMEC

Site: SCPT06-08
Location: ENBRIDGE KITIMAT

Cone: 15 375bar 199
Date: 07:14:06 17:34



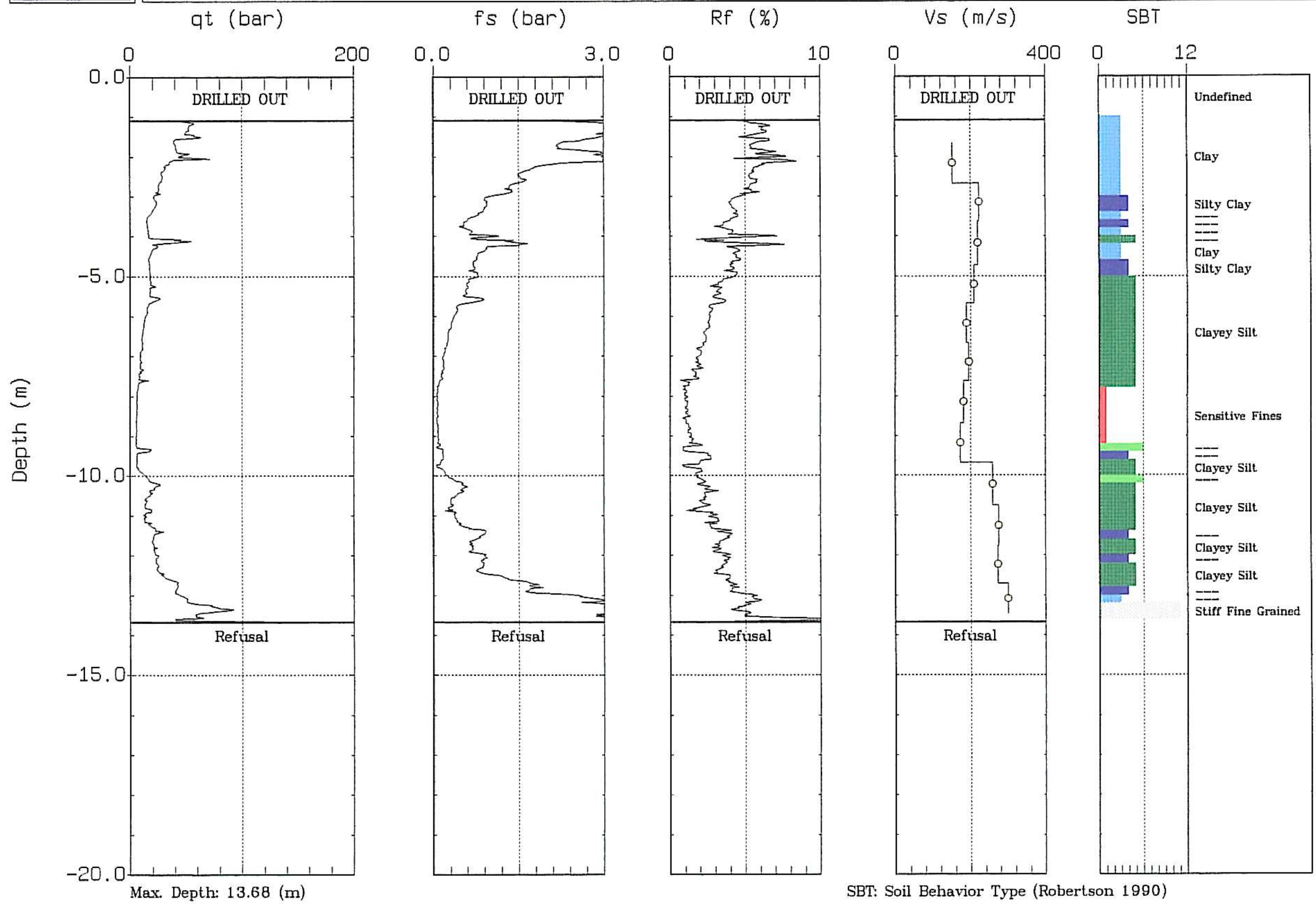
Max. Depth: 17.48 (m)
Depth Inc.: 0.025 (m)

SBT: Soil Behavior Type (Robertson 1990)

AMEC

Site: SCPT06-10
Location: ENBRIDGE KITIMAT

Cone: 15 375bar 199
Date: 07:13:06 10:14



Max. Depth: 13.68 (m)
Depth Inc.: 0.025 (m)

SBT: Soil Behavior Type (Robertson 1990)

Appendix VST
Vane Shear Testing

CONETEC

ConeTec Investigations Ltd.

Project No: 06-208
Client: AMEC
Site: Enbridge - Kitimat
Date: 7/19/2006 - 7/24/2006

Vane Shear Test Results

Vane Constants - C		**Torque Head Spring Constant - K:**	0.9310
Small Vane	0.20		
Medium Vane	0.10		
Large Vane	0.05		

Su (kPa) = 98.1 * K*c*a

Where: K is Torque Head Spring Constant
C is Vane Constant
A is distance (cm) on vane disk between peak and friction readings

Adjacent Test	Test Depth (ft)	Test Depth (m)	Test Date	Vane Used	Vane Constant	Peak a (cm)	Residual a (cm)	Remolded a (cm)	Su (kPa) Peak	Su (kPa) Residual	Su (kPa) Remolded
06-03	25.9	7.9	19-Jul-06	small	0.20	6.84	4.71	3.72	125	86	68
	45.9	14.0	19-Jul-06	small	0.20	3.50	2.50	2.38	64	46	43
06-04	13.1	4.0	23-Jul-06	small	0.20	9.39	6.82	4.31	172	125	79
	18.4	5.6	23-Jul-06	small	0.20	2.56	2.29	1.26	47	42	23
	24.6	7.5	23-Jul-06	small	0.20	2.25	1.88	0.86	41	34	16
06-05	16.1	4.9	21-Jul-06	small	0.20	5.89	5.61	4.21	108	102	77
	38.4	11.7	23-Jul-06	small	0.20	4.13	2.51	1.50	75	46	27
06-08	20.0	6.1	20-Jul-06	small	0.20	5.18	4.09	1.56	95	75	28
	23.3	7.1	21-Jul-06	small	0.20	4.43	1.41	1.27	81	26	23
	26.6	8.1	21-Jul-06	small	0.20	4.10	2.88	2.71	75	53	50
	39.4	12.0	21-Jul-06	medium	0.10	8.88	4.35	1.56	81	40	14
	42.8	13.1	21-Jul-06	medium	0.10	4.81	2.47	1.14	44	23	10
	46.8	14.3	21-Jul-06	medium	0.10	3.43	1.70	0.32	31	16	3
06-10	23.0	7.0	24-Jul-06	small	0.20	7.21	2.45	-	132	45	-
	25.9	7.9	24-Jul-06	small	0.20	2.99	2.35	2.35	55	43	43
	29.5	9.0	24-Jul-06	small	0.20	5.26	3.34	3.42	96	61	62
06-24	11.5	3.5	23-Jul-06	small *	0.20	9.90	-	-	181	-	-

Test Depths indicated are referenced to the middle of the vane

* Instrument out of range, Su shown is the maximum recorded without failing the soil

Appendix F Pipeline Valve Site Information

	Title
Table F-1	Preliminary Pipeline Valve Locations
Figure F-1	Pipeline Valve Site Plan – Typical with Helicopter Pad
Figure F-2	Pipeline Valve Site Plan – Typical with Existing Road Access

Table F-1 Preliminary Pipeline Valve Locations

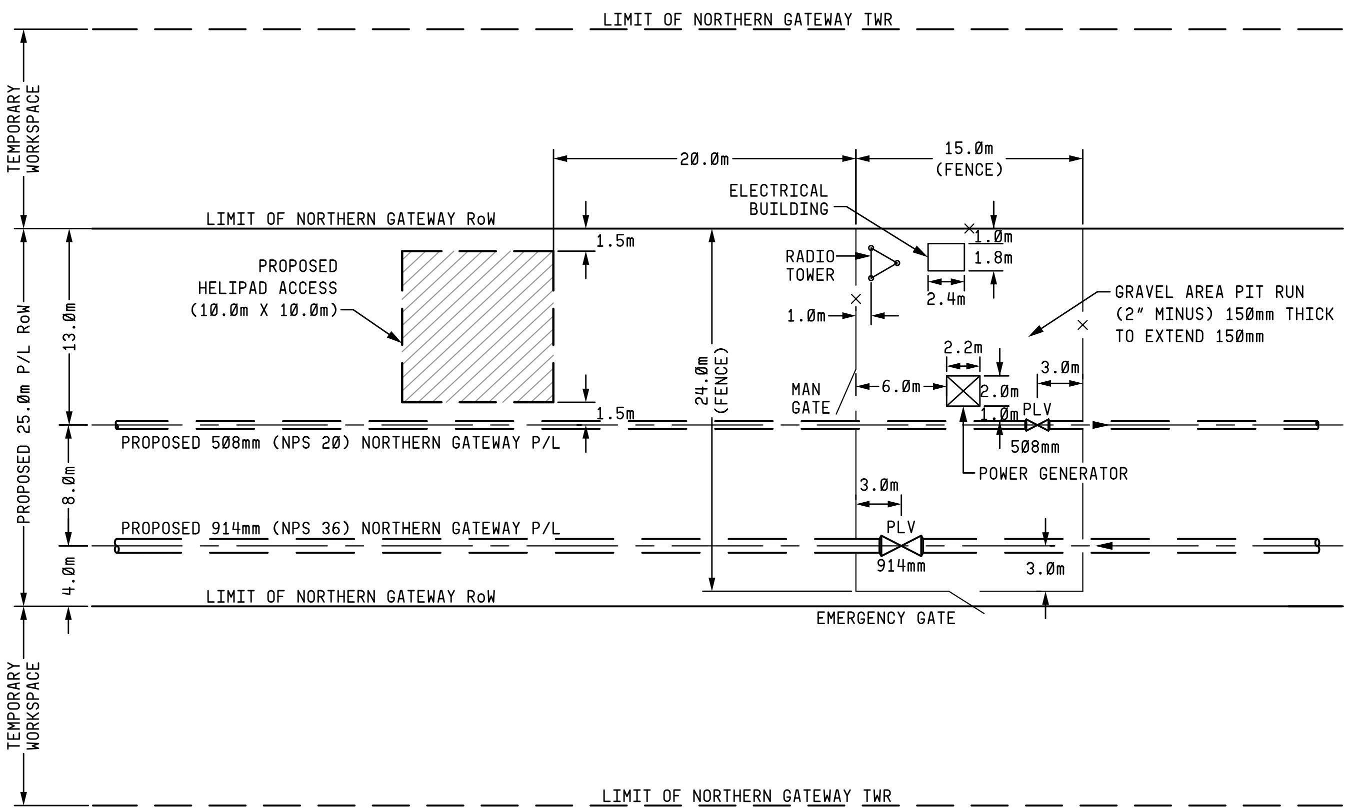
KP	Valve Location Description	Oil	Condensate
0.0	Bruderheim Pump Station	X	X
4.4	North Saskatchewan River	X	X
22.8	Tributary to Sturgeon River	X	X
130.4	Pembina River	X	X
137.9	Paddle River	X	X
138.9	Paddle River	X	X
186.7	Athabasca River	X	X
187.9	Athabasca River	X	X
199.3	Sakwatamau River	X	X
203.2	Whitecourt Pump Station	X	X
219.2	Chickadee Creek	X	
242.4	Two Creek	X	X
289.1	Little Smoky River	X	X
292.1	Little Smoky River	X	X
337.7	Deep Valley Creek	X	X
341.1	Tributary to Deep Valley Creek	X	X
358.8	Simonette River	X	X
360.5	Simonette River	X	X
371.3	Latornell River	X	X
373.3	Latornell River	X	X
394.9	Tributary to Smoky River #1	X	X
396.6	Tributary to Smoky River #1	X	X
400.6	Smoky River Pump Station	X	X
419.9	Smoky River	X	X
422.4	Smoky River	X	X
425.4	Braaten	X	X
436.1	Big Mountain Creek	X	X
444.9	Bald Mountain Creek,	X	X
446.3	Bald Mountain Creek	X	X
472.7	Pinto Creek	X	X
474.3	Pinto Creek	X	X
492.4	Wapiti River	X	X
495.1	Wapiti River	X	X

Table F-1 Preliminary Pipeline Valve Locations (cont'd)

KP	Valve Location Description	Oil	Condensate
519.1	Hiding Creek	X	X
532.6	South Redwillow River	X	X
561.2	Kinuseo Creek #1	X	X
565.5	Kinuseo Creek #2	X	X
588.4	Kinuseo Creek #3	X	X
596.2	Tributary to Murray River	X	X
598.0	Tumbler Ridge Pump Station	X	X
602.0	Hook Creek	X	X
603.4	Hook Creek	X	X
641.1	Missinka River East	X	X
646.5	Missinka River West	X	X
670.9	Parsnip River	X	X
672.2	Parsnip River	X	X
702.3	Chuchinka River	X	X
703.6	Chuchinka River	X	X
716.0	Bear Lake Pump Station	X	X
717.5	Crooked River	X	X
719.7	Crooked River	X	X
762.6	Salmon River	X	X
764.0	Salmon River	X	X
816.0	Necoslie River	X	X
818.3	Necoslie River	X	X
824.6	Fort St. James Pump Station	X	X
854.9	Sutherland River	X	X
863.9	Duncan Creek	X	X
864.6	Duncan Creek	X	X
919.0	Stearns Creek	X	X
925.5	Burns Lake Pump Station	X	X
928.7	Endako River	X	X
930.7	Endako River	X	X
948.0	Maxan Creek	X	X
948.5	Maxan Creek	X	X
965.0	Foxy Creek #2	X	X

Table F-1 Preliminary Pipeline Valve Locations (cont'd)

KP	Valve Location Description	Oil	Condensate
975.0	Klo Creek	X	X
986.0	Buck Creek	X	X
1002.1	Houston Pump Station	X	X
1002.7	Owen Creek	X	X
1012.7	24.5 Mile Creek	X	X
1044.8	Crystal Creek	X	X
1056.5	Gosnell Creek	X	X
1059.3	Gosnell Creek	X	X
1071.9	Clore River	X	X
1079.4	Tributary to Clore River	X	X
1086.9	Hoult Creek	X	X
1124.7	Clearwater Pump Station	X	X
1143.3	Wedeene River	X	X
1148.4	Little Wedeene River	X	X
1149.4	Little Wedeene River	X	X
1153.3	Tributary to Kitimat River #5	X	X
1172.2	Kitimat Terminal	X	X



SITE PLAN

SCALE - 1:500

NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS SHOWN OTHERWISE.
2. ADDITIONAL EXTRA TEMPORARY WORK SPACE WILL BE REQUIRED ADJACENT TO THE SITE. FOR INSTALLATION WHICH WILL BE DETERMINED DURING DETAIL ENGINEERING.

LEGEND:

CONSTRUCTION RoW LIMIT

PROPOSED PIPELINE

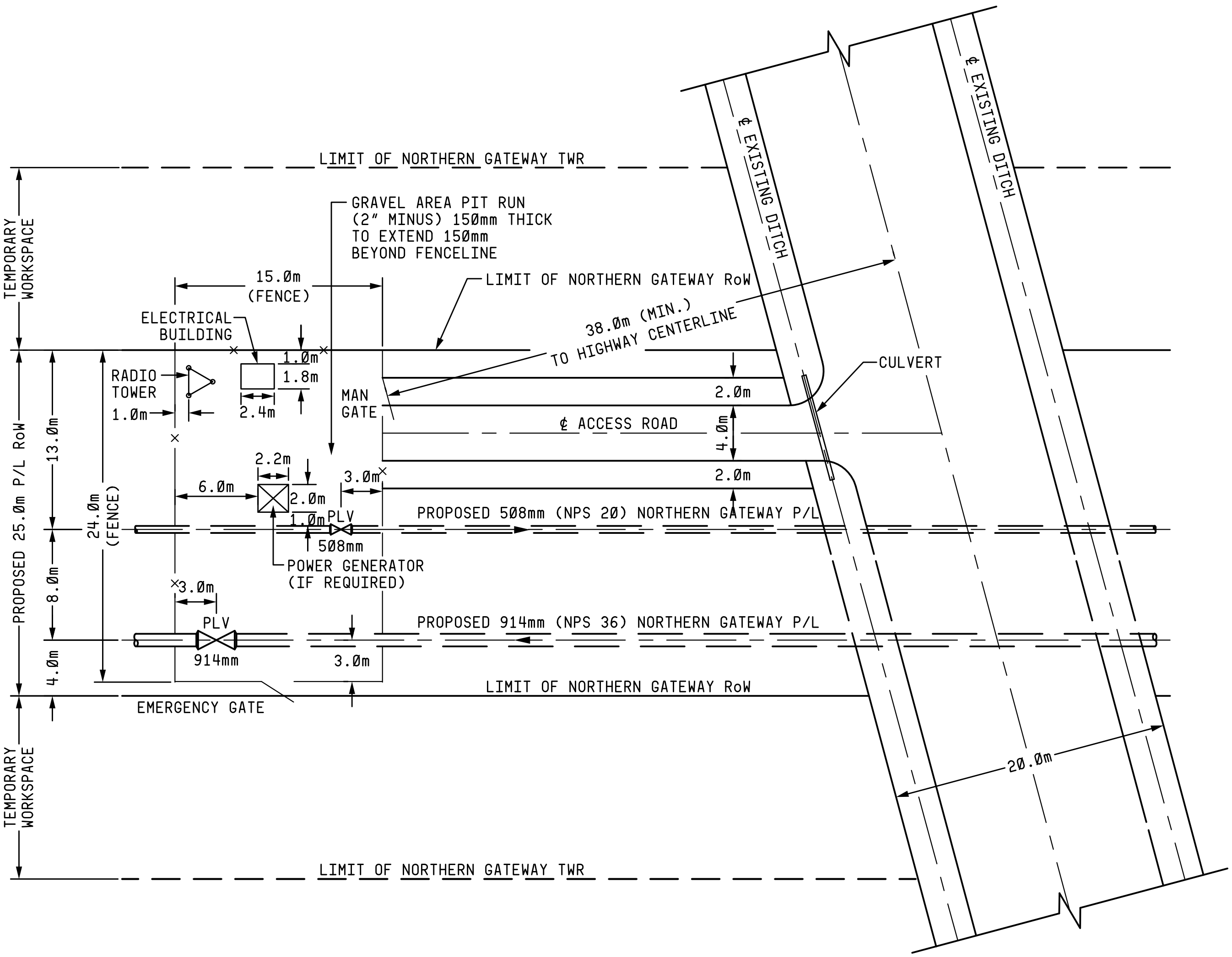
SECURITY FENCE

CENTERLINE OF ROAD

PROPOSED RIGHT-OF-WAY

TEMPORARY WORKING RIGHTS

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION D DATE 19 OCT 2009
	914mm & 508mm PIPELINE VALVE SITE PLAN—TYPICAL WITH HELICOPTER PAD	FIGURE NO. F—1



SITE PLAN

SCALE - 1:500

NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS SHOWN OTHERWISE.
2. ADDITIONAL EXTRA TEMPORARY WORK SPACE WILL BE REQUIRED ADJACENT TO THE SITE. FOR INSTALLATION WHICH WILL BE DETERMINED DURING DETAIL ENGINEERING.
3. ACCESS ROAD TO BE CONSTRUCTED FROM EXISTING PERMANENT ROAD.

LEGEND:

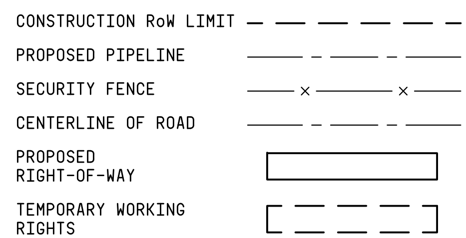


FIGURE ID	
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT
	914mm & 508mm PIPELINE VALVE SITE PLAN—TYPICAL WITH EXISTING ROAD ACCESS
SCALE	N.T.S.
REVISION	D
DATE	19 OCT 2009
FIGURE NO.	F-2

Appendix G.1 Pipeline Watercourse Crossing Information

Information	Title
Table G-1	Watercourse Crossing Methods for Review Sites
Figure G-1	Watercourse Crossing – Open Cut of Small Watercourses
Figure G-2	Watercourse Crossing – Isolation: Dam and Pump
Figure G-3	Watercourse Crossing – Isolation: Flume
Figure G-4	Watercourse Crossing – Trenchless: Bore/Punch
Figure G-5a	Watercourse Crossing – Large Directional Drill – Cross Section
Figure G-5b	Watercourse Crossing – Large Directional Drill – Plan View
Figure G-6	Pipeline Watercourse Crossing Decision Flowchart, Stage 1 – Initial Screening
Figure G-7	Pipeline Watercourse Crossing Decision Flowchart, Stage 2 – Review Sites
Figure G-8	Vehicle Crossing – Snow Fill
Figure G-9	Vehicle Crossing – Typical Ice Bridge
Figure G-10	Vehicle Crossing – Typical Ramp and Culvert
Figure G-11	Vehicle Crossing – Typical Temporary Bridge

Table G-1. Watercourse Crossing Methods for Review Sites

KP	Watercourse Name	Proposed Crossing Method (Construction Timing)[a]	Alternative Crossing Method (Construction Timing)[a]
4.0	North Saskatchewan River	Open Cut (Summer)	Open Cut (Winter)
131.6	Pembina River	HDD	Isolated (Winter)
138.2	Paddle River	Isolated (December to April)	Isolated (Summer)
164.0	Little Paddle River	Isolated (December to April)	Isolated (Summer)
187.4	Athabasca River	HDD	Open Cut (Winter)
200.4	Sakwatamau River	Isolated (Winter)	Open Cut (July 16 to August 31)
218.9	Chickadee Creek	Isolated (Winter)	Isolated (Summer)
241.8	Two Creek	Isolated (Winter)	Isolated (Summer)
259.1	Iosegun River	Isolated (Winter)	Isolated (Summer)
272.1	Tributary to Iosegun Lake	Open Cut if frozen (November to February)	Isolated (November to February)
272.2	Tributary to Iosegun Lake	Open Cut if frozen (November to February)	Isolated (November to February)
272.3	Tributary to Iosegun Lake	Open Cut if frozen (November to February)	Isolated (November to February)
272.5	Tributary to Iosegun Lake	Open Cut if frozen (November to February)	Isolated (November to February)
274.4	Tributary to Iosegun Lake	Open Cut if frozen (November to February)	Isolated (November to February)
275.1	Tributary to Iosegun Lake	Open Cut if frozen (November to February)	Isolated (November to February)
291.0	Little Smoky River	Isolated (Winter)	Open Cut (July to August)
318.2	Waskahigan River	Isolated (Winter)	Isolated (Summer)
338.8	Deep Valley Creek	Isolated (Winter)	Isolated (Summer)

KP	Watercourse Name	Proposed Crossing Method (Construction Timing)[a]	Alternative Crossing Method (Construction Timing)[a]
340.7	Tributary to Deep Valley Creek	Isolated (Winter)	Isolated (Summer)
360.0	Simonette River	Bore	Open Cut (July 16 to July 31)
371.9	Latornell River	Isolated (Winter)	Isolated (Summer)
395.7	Patterson Creek	Isolated (Winter)	Isolated (Summer)
404.3	Tributary to Smoky River	Isolated (Winter)	Isolated (Summer)
421.6	Smoky River	HDD	Open Cut (Winter)
431.8	Gold Creek	Isolated (Winter)	Isolated (Summer)
435.3	Big Mountain Creek	Isolated (Winter)	Isolated (Summer)
445.9	Bald Mountain Creek	Isolated (Winter)	Isolated (Summer)
473.4	Pinto Creek	Bore	Isolated (Summer)
493.3	Wapiti River	HDD	Open Cut (November to February)
517.9	Hiding Creek	Isolated (December to April)	Isolated (Summer)
531.9	South Redwillow River	Isolated (Winter)	Isolated (Summer)
561.5	Kinuseo Creek	Isolated (July to August)	Open Cut (July 15 to August 15)
566.0	Kinuseo Creek	Isolated (July to August)	Open Cut (July 15 to August 15)
580.8	Five Cabin Creek	Isolated (Summer)	Open Cut (July 15 to August 15)
588.1	Kinuseo Creek	Bore	Open Cut (July 15 to August 15)
597.1	Tributary to Murray River	Isolated (July to August)	Open Cut (July to August)
598.6	Murray River	Aerial	N/A
602.5	Hook Creek	HDD	Isolated (July to August)

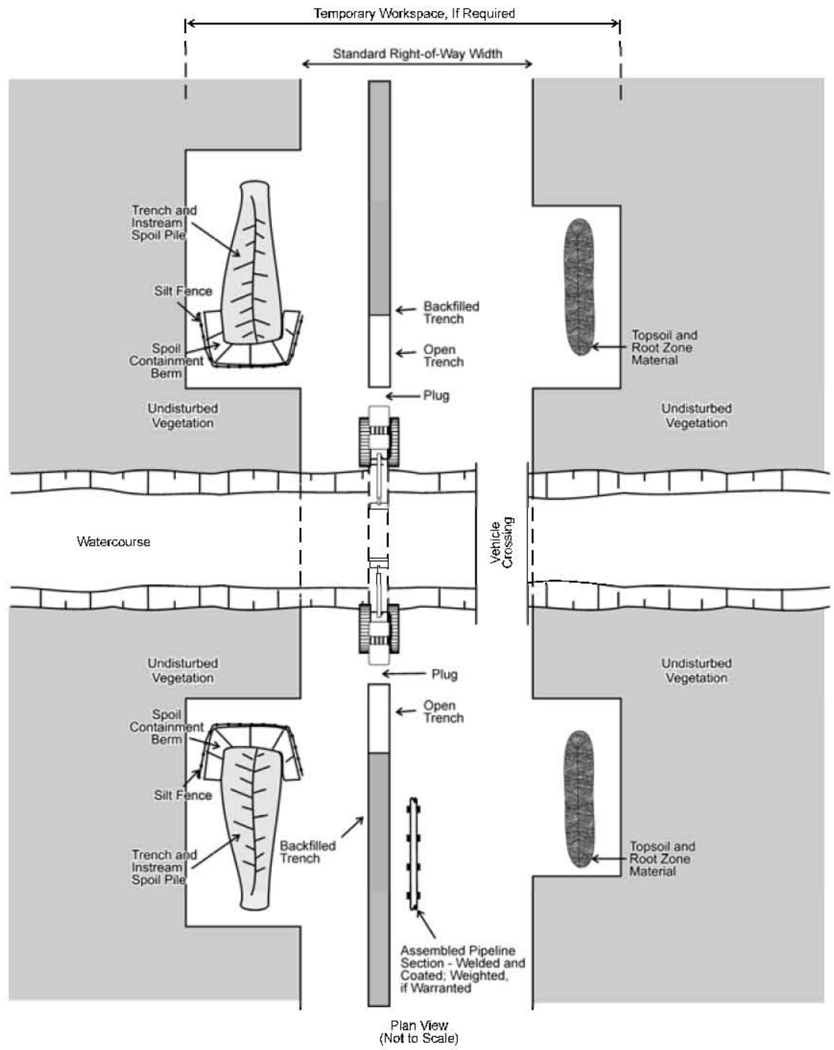
KP	Watercourse Name	Proposed Crossing Method (Construction Timing)[a]	Alternative Crossing Method (Construction Timing)[a]
619.8	Tributary to Imperial Creek	Open Cut (Anytime)	N/A
641.3	Missinka River	Bore	Open Cut (July 15 to August 15)
646.0	Missinka River	Open Cut (July 15 to August 15)	N/A
671.0	Parsnip River	HDD	Open Cut (July 15 to August 15)
703.1	Chuchinka Creek	Isolated (August)	Open Cut (July 15 to August 15)
710.4	Angusmac Creek	Isolated (August)	Open Cut (July 15 to August 31)
718.2	Crooked River	Bore	Open Cut (July 15 to August 31)
748.1	Muskeg River	Bore	Isolated (Winter)
763.0	Salmon River	Bore	Isolated (Winter)
780.3	Tributary to Great Beaver Lake	Isolated (Winter)	Isolated (Summer)
816.4	Necoslie River	Bore	Isolated (Winter)
821.9	Stuart River	HDD	Other Trenchless
856.2	Sutherland River	Isolated (January to March)	Isolated (Summer)
864.2	Tributary to Duncan Creek	Isolated (December to April)	Isolated (Summer)
929.3	Endako River	Bore	Isolated (Winter)
948.2	Maxan Creek	Isolated (Summer)	Open Cut (Summer)
960.5	Foxy Creek	Isolated (August to March)	Open Cut (August to March)
964.5	Foxy Creek	Isolated (August to March)	Open Cut (August to March)
975.3	Klo Creek	Isolated (September to January)	Open Cut (September to January)
986.7	Buck Creek	Bore	Isolated (Summer)

KP	Watercourse Name	Proposed Crossing Method (Construction Timing)[a]	Alternative Crossing Method (Construction Timing)[a]
993.1	Parrott Creek	Isolated (August to March)	Open Cut (August to March)
1002.5	Owen Creek	Bore	Isolated (August to September)
1007.8	Fenton Creek	Isolated (August)	Open Cut (August)
1013.5	24.5 Mile Creek	Isolated (Summer)	Open Cut (Summer)
1018.5	Lamprey Creek	Bore	Isolated (August to September)
1025.7	Cedric Creek	Isolated (Summer)	Open Cut (Summer)
1038.0	Morice River	HDD	Other Trenchless
1044.4	Crystal Creek	Bore	Isolated (August to September)
1058.9	Gosnell Creek	Bore	Isolated (Winter)
1071.2	Tributary to Burnie River	Bore	Isolated (August to March)
1072.5	Clore River	Bore	Isolated (Winter)
1079.8	Tributary to Clore River	Aerial	N/A
1086.9	Hoult Creek	Aerial	N/A
1098.7	Hunter Creek	HDD	Isolated (Winter)
1109.4	Tributary to Kitimat River	Open Cut (Anytime)	N/A
1123.1	Chist Creek	Bore	Isolated (January to March)
1131.4	Cecil Creek	Bore	Isolated (Summer)
1140.0	Deception Creek	Isolated (Summer)	Open Cut (Summer)
1144.6	Wedeene River	HDD	Other Trenchless
1148.7	Little Wedeene River	Bore	Isolated (January to April)

KP	Watercourse Name	Proposed Crossing Method (Construction Timing)[a]	Alternative Crossing Method (Construction Timing)[a]
1154.5	Tributary to Kitimat River	Isolated (July to August)	Open Cut (July to August)
1156.7	Duck Creek	Isolated (July to August)	Open Cut (July to August)
1161.0	Tributary to Kitimat River	Isolated (July to August)	Open Cut (July to August)
1163.8	Anderson Creek	Isolated (Winter)	Isolated (August)
1165.0	Moore Creek	Aerial	N/A

NOTES:

[a] All watercourse crossing methods and construction timings are preliminary and will be finalized during detailed engineering.



Source: Adapted from CAPP *et al.* 2005

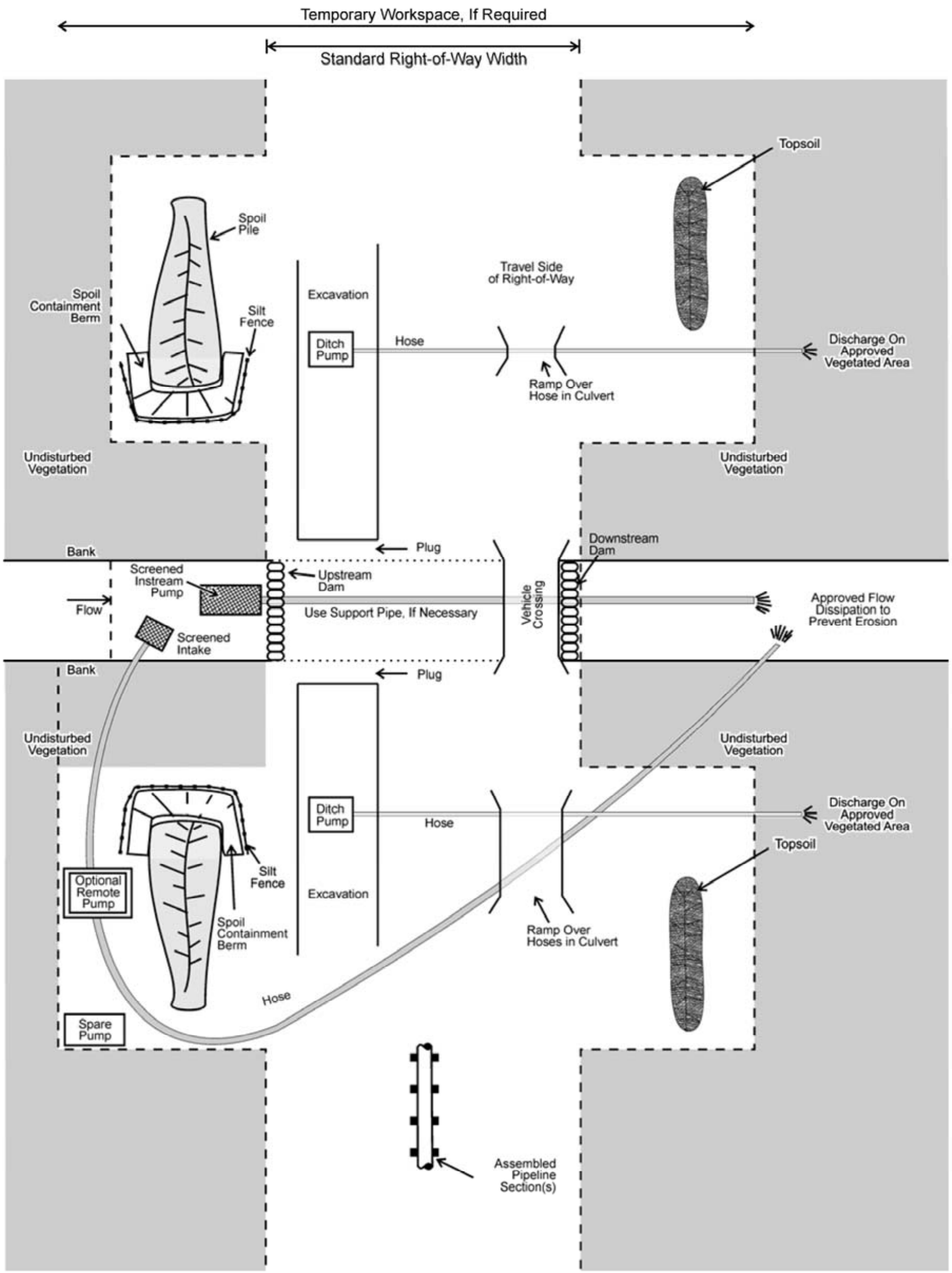
ENBRIDGE NORTHERN GATEWAY PIPELINES

Enbridge Northern Gateway Project

WATERCOURSE CROSSING – OPEN CUT OF SMALL WATERCOURSES

March 2010

Figure G -1



Plan View
(Not to Scale)

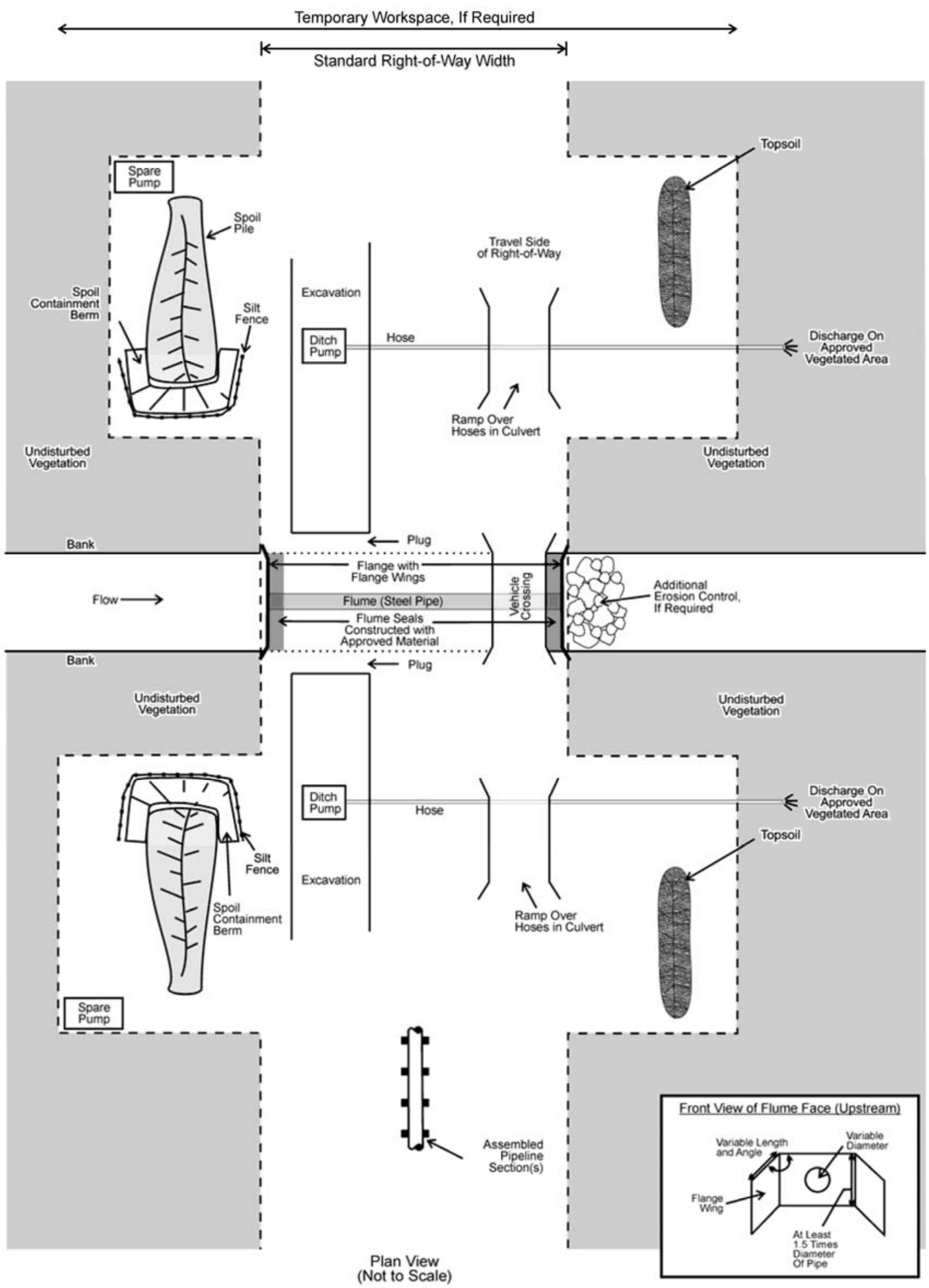
Adapted from CAPP *et al.* (2005)

ENBRIDGE NORTHERN GATEWAY PIPELINES

Enbridge Northern Gateway Project

WATERCOURSE CROSSING – ISOLATION: DAM AND PUMP

March 2010	Figure G - 2



Adapted from CAPP *et al.* (2005)

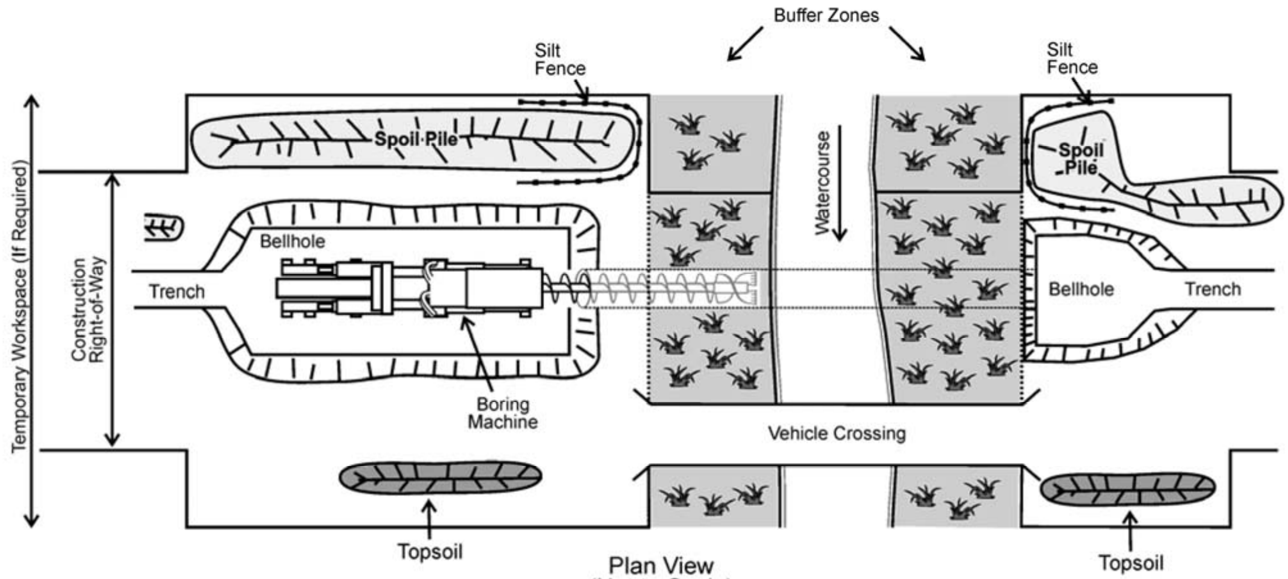
ENBRIDGE NORTHERN GATEWAY PIPELINES

Enbridge Northern Gateway Project

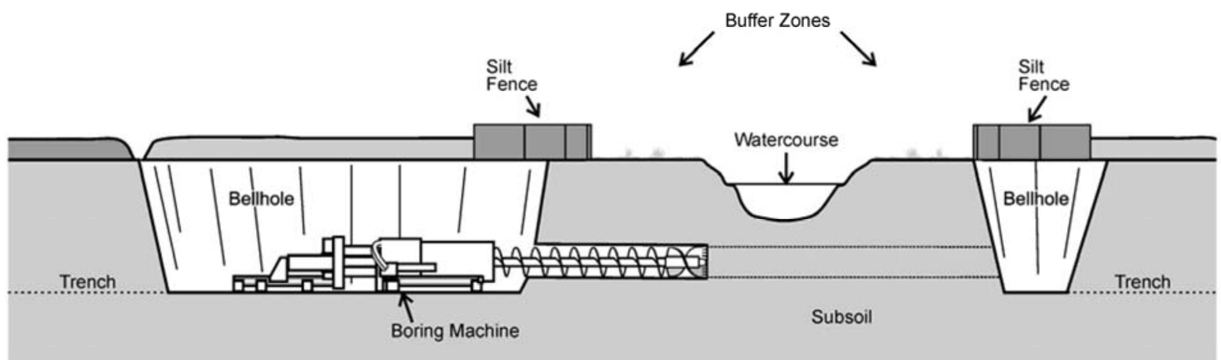
WATERCOURSE CROSSING – ISOLATION: FLUME

March 2010

Figure G - 3



Plan View
(Not to Scale)



Profile
(Not to Scale)

Adapted from CAPP *et al.* (2005)

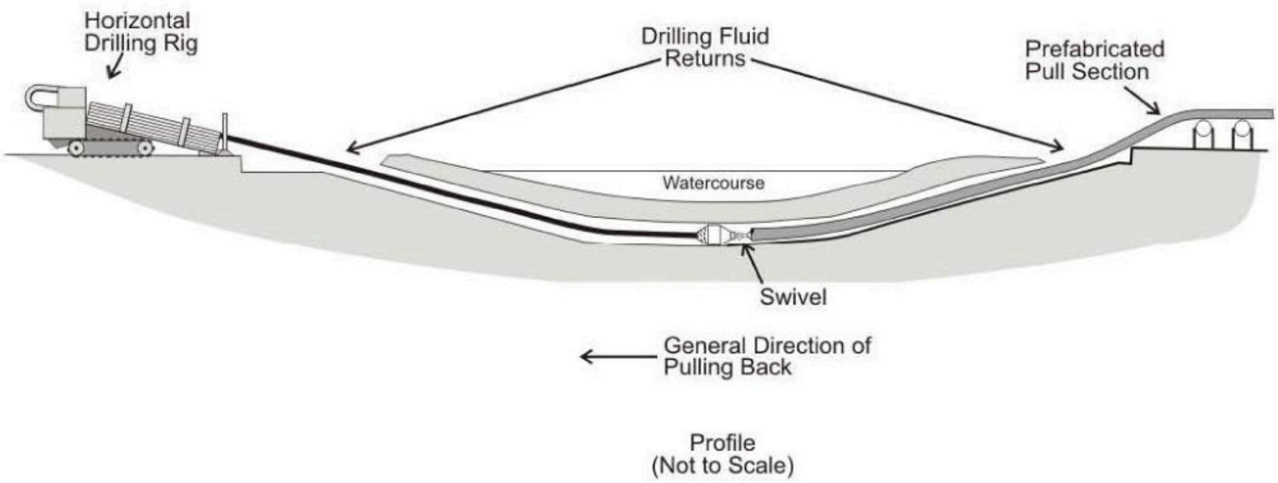
ENBRIDGE NORTHERN GATEWAY PIPELINES

Enbridge Northern Gateway Project

WATERCOURSE CROSSING – TRENCHLESS: BORE / PUNCH

March 2010

Figure G - 4



Adapted from CAPP *et al.* (2005)

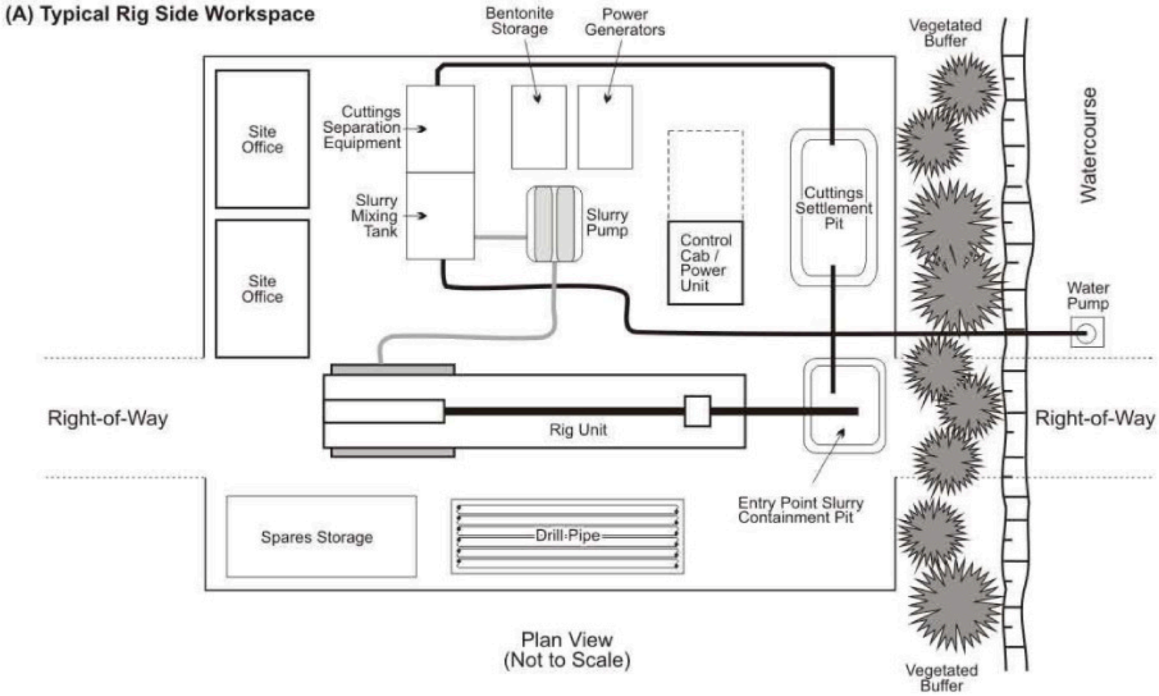
ENBRIDGE NORTHERN GATEWAY PIPELINES

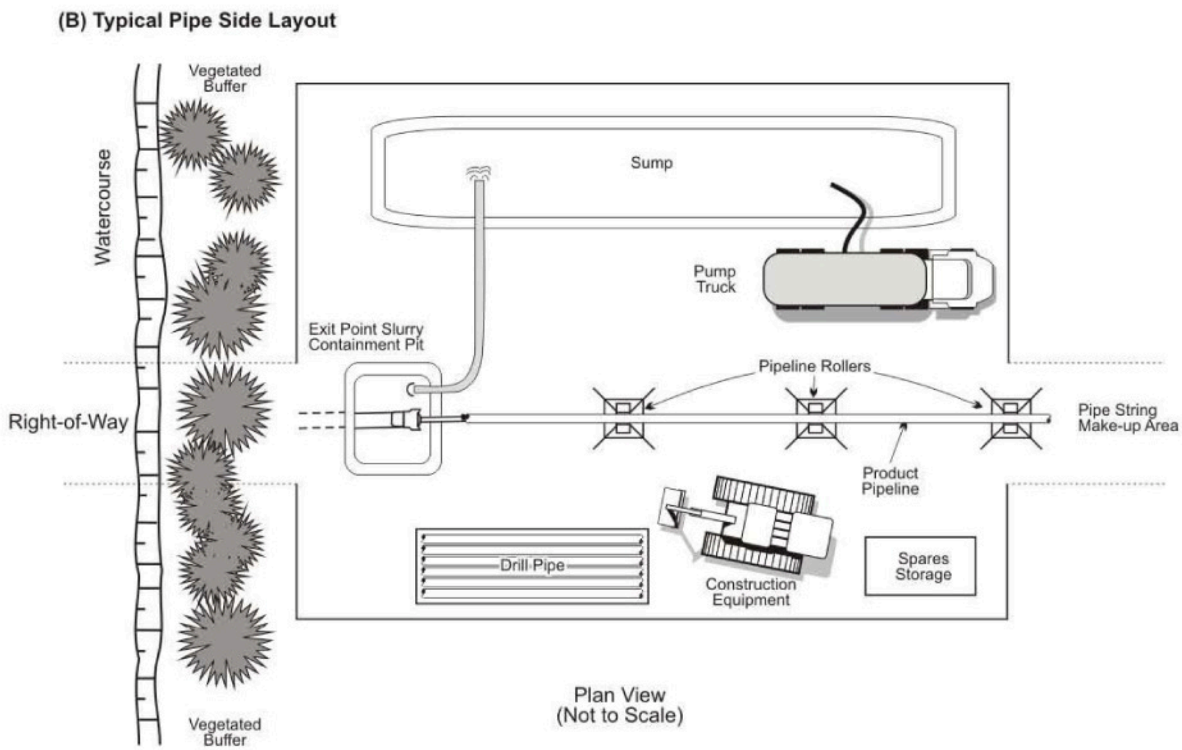
Enbridge Northern Gateway Project

WATERCOURSE CROSSING – LARGE DIRECTIONAL DRILL – CROSS-SECTION

March 2010

Figure G – 5a





Adapted from CAPP *et al.* (2005)

ENBRIDGE NORTHERN GATEWAY PIPELINES

Enbridge Northern Gateway Project

WATERCOURSE CROSSING – LARGE DIRECTIONAL DRILL – PLAN VIEW

March 2010	Figure G – 5b

Figure G-6: Pipeline Watercourse Crossing Decision Flowchart, Stage 1 – Initial Screening

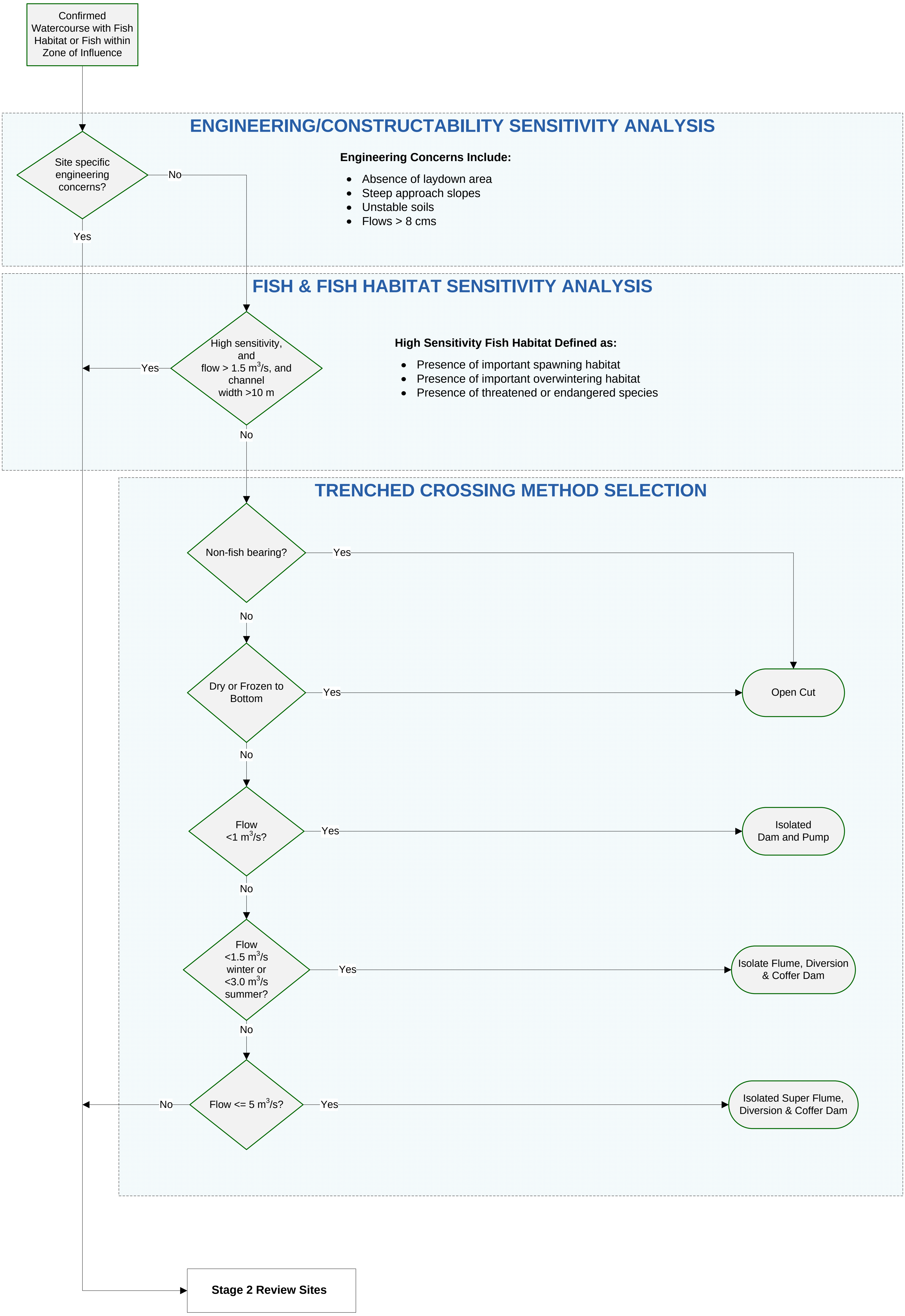
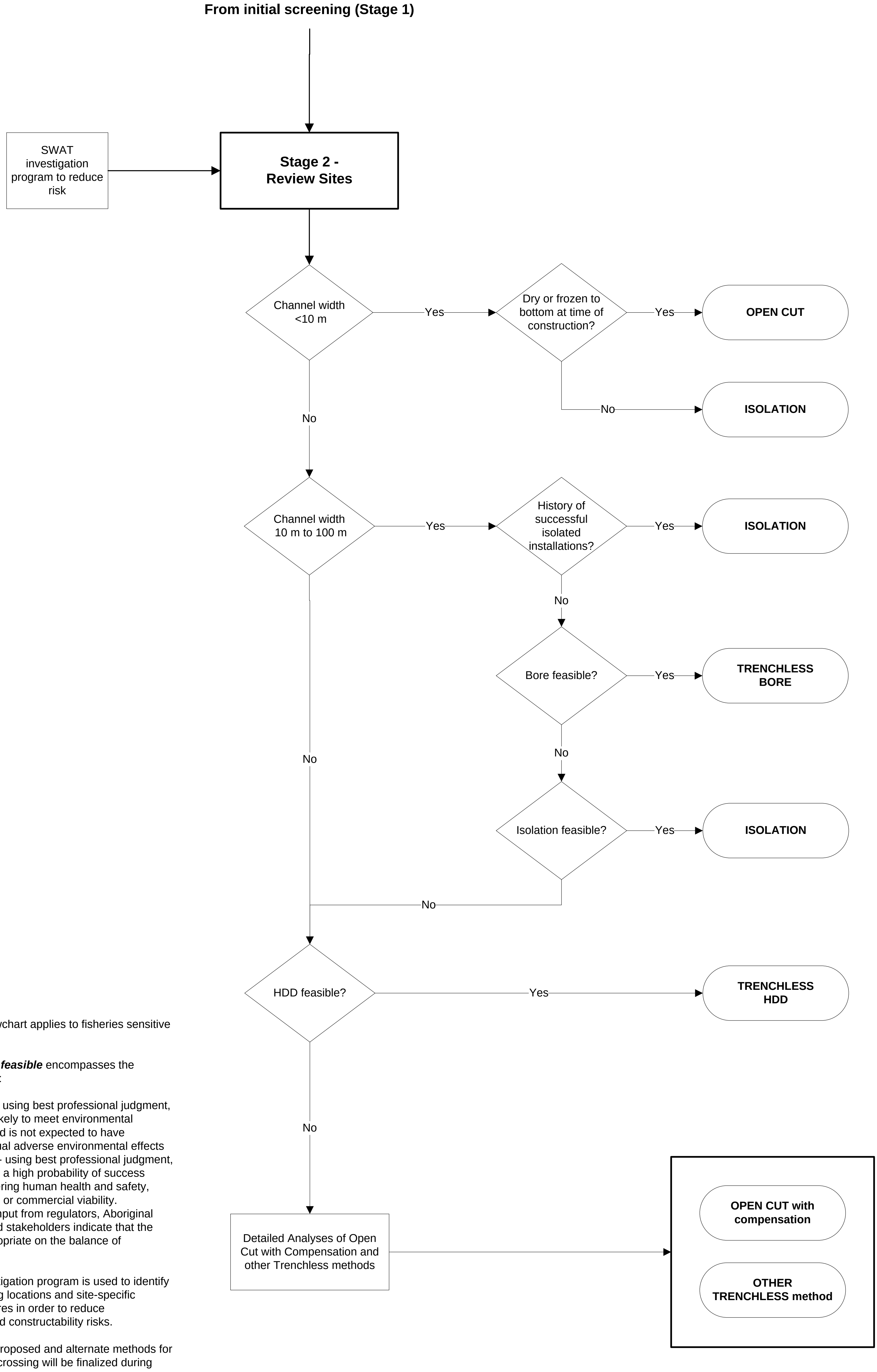


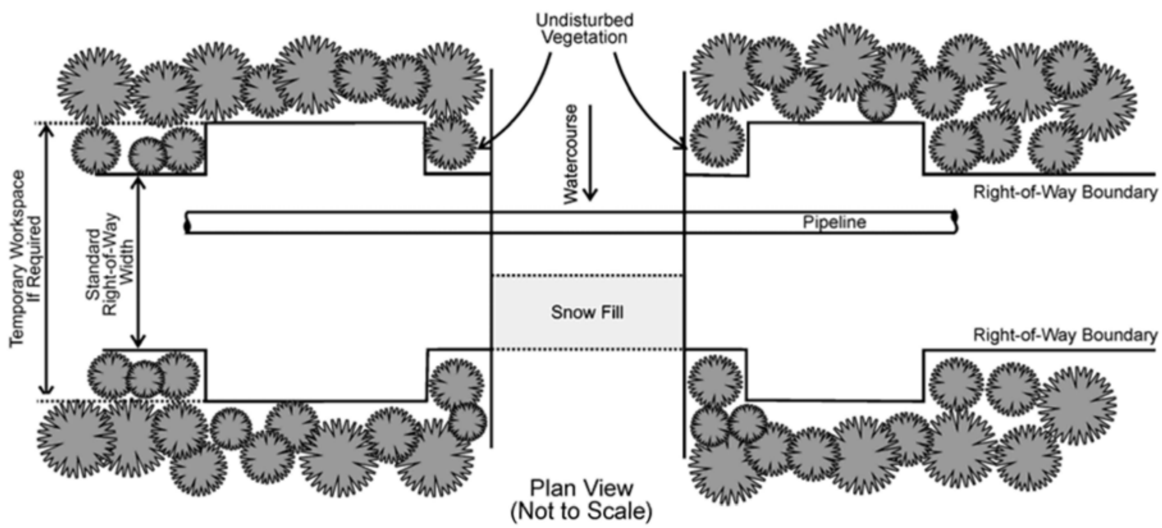
Figure G-7: Pipeline Watercourse Crossing Decision Flowchart, Stage 2 - Review Sites



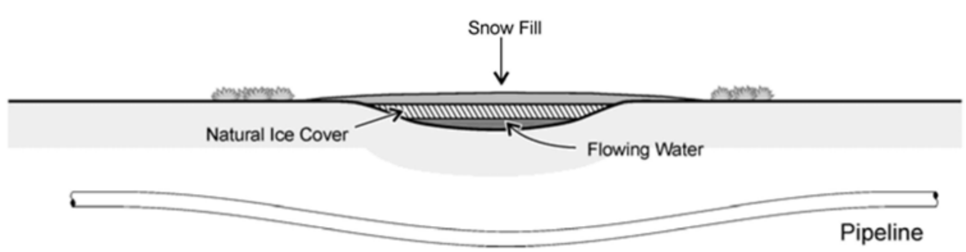
Notes:

1. This decision flowchart applies to fisheries sensitive review sites.
2. For this analysis, ***feasible*** encompasses the following aspects:
   - Environmental – using best professional judgment, the crossing is likely to meet environmental requirements and is not expected to have significant residual adverse environmental effects
   - Constructability - using best professional judgment, the crossing has a high probability of success without endangering human health and safety, project schedule or commercial viability.
   - Consultation – input from regulators, Aboriginal communities and stakeholders indicate that the crossing is appropriate on the balance of considerations
3. The SWAT investigation program is used to identify preferred crossing locations and site-specific mitigative measures in order to reduce environmental and constructability risks.
4. Selection of the proposed and alternate methods for each review site crossing will be finalized during detailed design.

A. Plan View



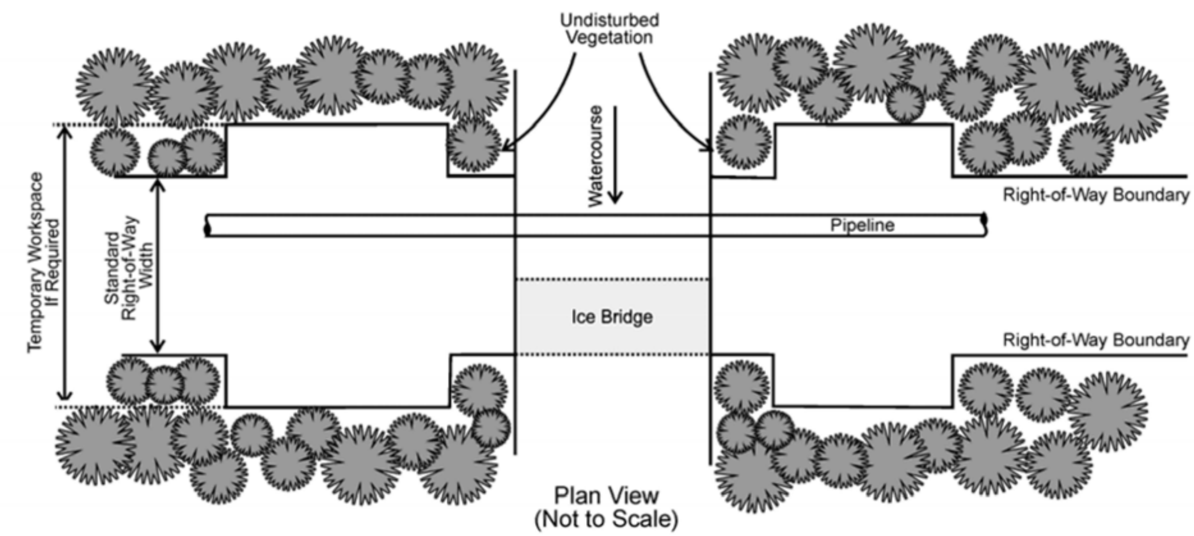
B. Profile View



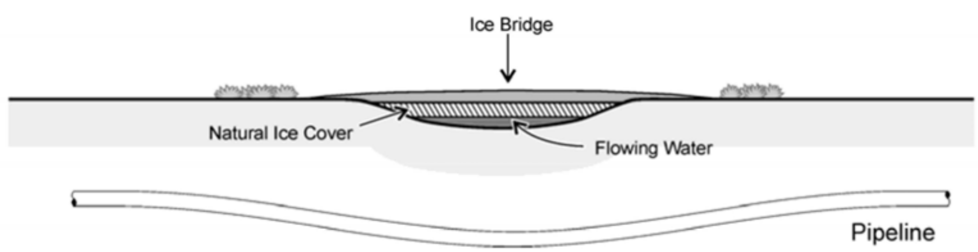
Adapted from CAPP *et al.* (2005)

ENBRIDGE NORTHERN GATEWAY PIPELINES	Enbridge Northern Gateway Project
	VEHICLE CROSSING - SNOW FILL
	March 2010 / Figure G - 8

A. Plan View



B. Profile View

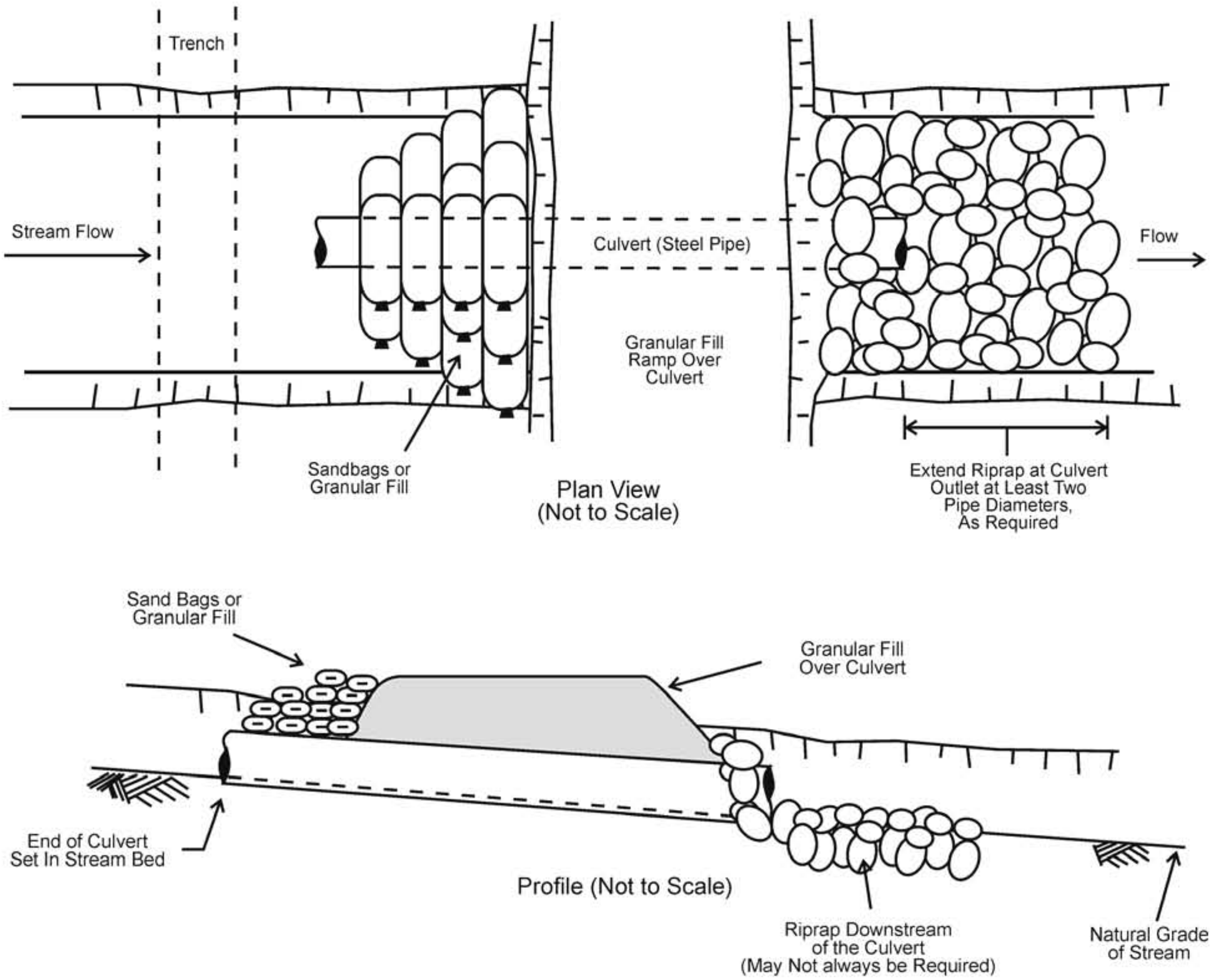


Adapted from CAPP *et al.* (2005)

Enbridge Northern Gateway Project

VEHICLE CROSSING - TYPICAL ICE BRIDGE

	March 2010	Figure G- 9



Source: Adapted from CAPP *et al.* (2005)

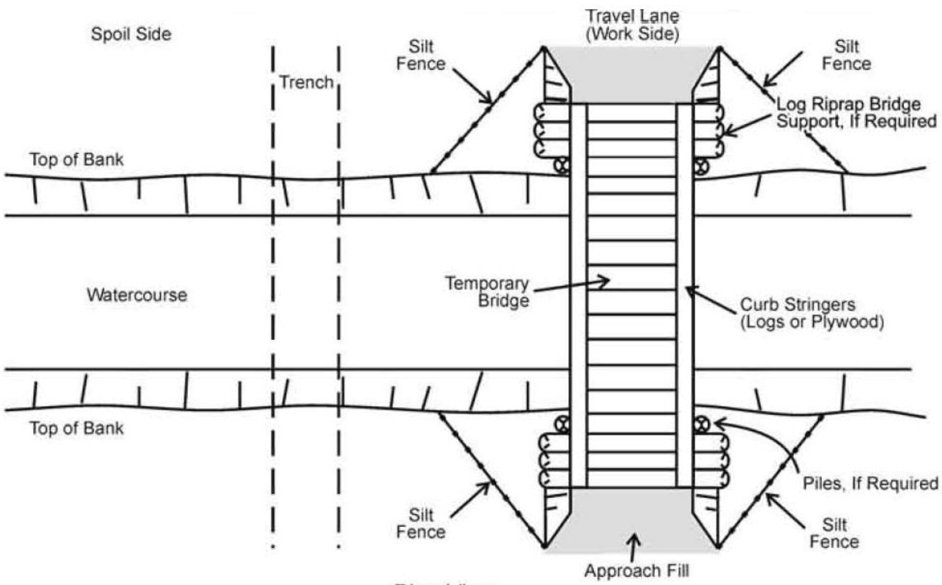
ENBRIDGE NORTHERN GATEWAY PIPELINES

Enbridge Northern Gateway Project

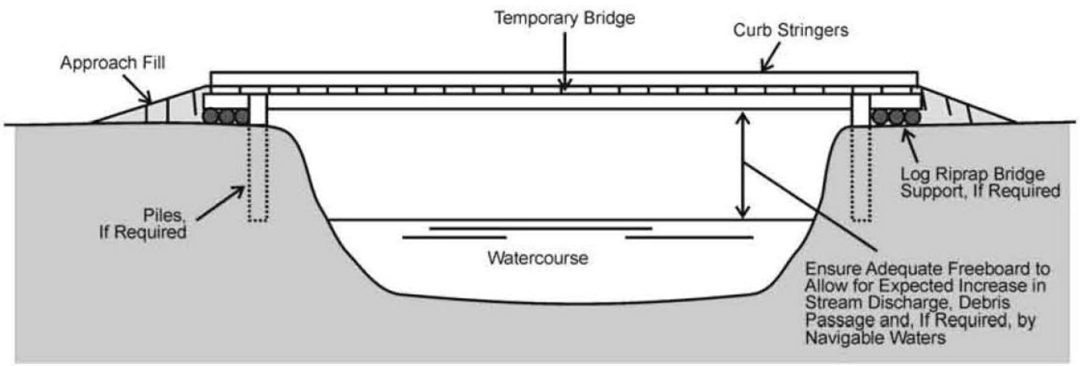
VEHICLE CROSSING - TYPICAL RAMP AND CULVERT

March 2010

Figure G -10



Plan View
(Not to Scale)



Profile
(Not to Scale)

Adapted from CAPP *et al.* (2005)

ENBRIDGE NORTHERN GATEWAY PIPELINES

Enbridge Northern Gateway Project

VEHICLE CROSSING - TYPICAL TEMPORARY BRIDGE

March 2010

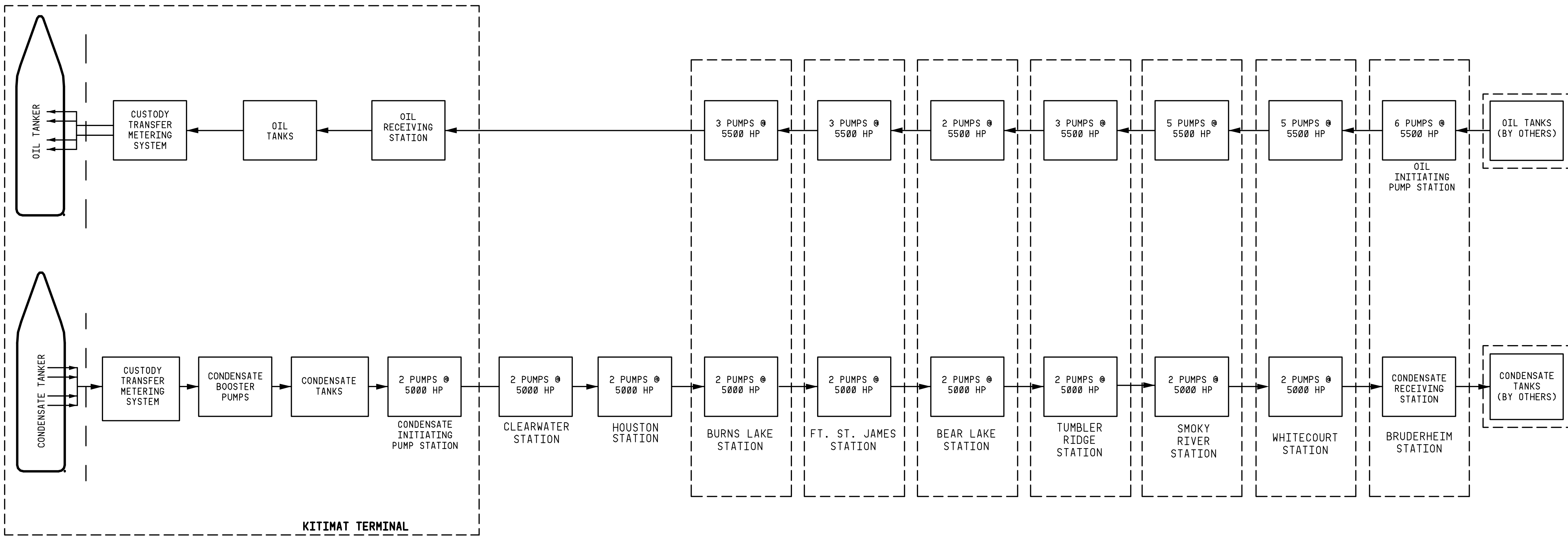
Figure G - 11

Appendix G.2 Preliminary HDD Feasibility Assessment Reports

(To be provided later as an update.)

Appendix H Pump Station Site Drawings

Figure No.	Description
H-1	Oil and Condensate Pipeline System Flow Diagram
H-2	Bruderheim Station Oil Initiating Pump Station Plot Plan
H-3	Whitecourt Station Dual Pump Station Plot Plan
H-4	Smoky River Station Dual Pump Station Plot Plan
H-5	Tumbler Ridge Station Dual Pump Station Plot Plan
H-6	Bear Lake Station Dual Pump Station Plot Plan
H-7	Fort St. James Station Dual Pump Station Plot Plan
H-8	Burns Lake Station Dual Pump Station Plot Plan
H-9	Houston Station Condensate Pump Station with Scraper Traps Plot Plan
H-10	Clearwater Station Condensate Pump Station with Scraper Traps Plot Plan
H-11	Bruderheim Station Oil Initiating Pumps Process Flow Diagram
H-12	Bruderheim Station Condensate Receiving Trap Process Flow Diagram
H-13	Whitecourt Station Oil Pumps Process Flow Diagram
H-14	Whitecourt Station Condensate Pumps Process Flow Diagram
H-15	Smoky River Station Oil Pumps Process Flow Diagram
H-16	Smoky River Station Condensate Pumps Process Flow Diagram
H-17	Tumbler Ridge Station Oil Pumps Process Flow Diagram
H-18	Tumbler Ridge Station Condensate Pumps Process Flow Diagram
H-19	Bear Lake Station Oil Pumps Process Flow Diagram
H-20	Bear Lake Station Condensate Pumps Process Flow Diagram
H-21	Fort St. James Station Oil Pumps Process Flow Diagram
H-22	Fort St. James Station Condensate Pumps Process Flow Diagram
H-23	Burns Lake Station Oil Pumps Process Flow Diagram
H-24	Burns Lake Station Condensate Pumps Process Flow Diagram
H-25	Houston Station Condensate Pumps Process Flow Diagram
H-26	Clearwater Station Condensate Pumps Process Flow Diagram



NOTES ON OIL PIPELINE:

1. AVERAGE DAILY CAPACITY IS 83,400 CUBIC METRES.
2. THE PIPELINE WILL BE CONSTRUCTED WITH 914mm OD, GRADE 483 STEEL LINE PIPE.
3. A PIG LAUNCHER WILL BE CONSTRUCTED AT THE BRUDERHEIM STATION. A PIG RECEIVER WILL BE CONSTRUCTED AT THE KITIMAT TERMINAL.
4. A PIG LAUNCHER AND RECEIVER WILL BE CONSTRUCTED AT EACH INTERMEDIATE PUMP STATION, AS REQUIRED.
5. AN AUTOMATED PIG BYPASS LOOP WILL BE CONSTRUCTED AT THE INTERMEDIATE OIL PUMP STATIONS.

NOTES ON CONDENSATE PIPELINE:

1. AVERAGE ANNUAL DAILY CAPACITY IS 30,700 CUBIC METRES.
2. THE PIPELINE WILL BE CONSTRUCTED WITH 508mm OD, GRADE 483 STEEL LINE PIPE.
3. A PIG LAUNCHER WILL BE CONSTRUCTED AT THE KITIMAT STATION. A PIG RECEIVER WILL BE CONSTRUCTED AT THE BRUDERHEIM STATION.
4. A PIG LAUNCHER AND RECEIVER WILL BE CONSTRUCTED AT EACH INTERMEDIATE PUMP STATION, AS REQUIRED.

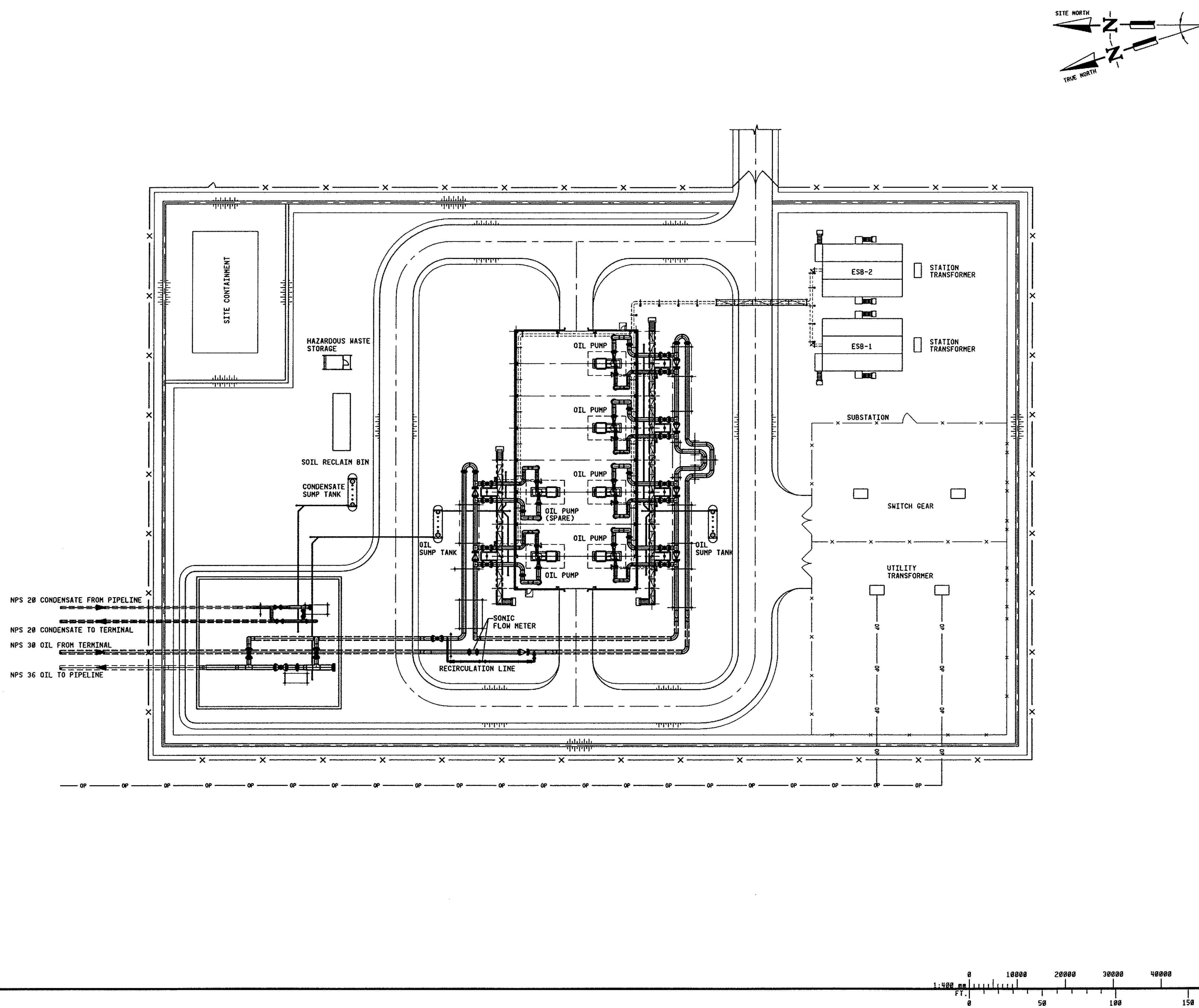
NO	REVISION	DATE/BY	APPROVE
A	ISSUED FOR NEB APPLICATION	12 MAY 09 SC	

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
OIL AND CONDENSATE PIPELINE SYSTEM
FLOW DIAGRAM

DRAWN	SC	CHECK	JI	APPROVE
DATE	12 MAR 09	SCALE	AS SHOWN	APPROVE

H-1



NOTES

1. SMALL BORE PIPING NOT SHOWN FOR CLARITY.
2. LARGE BORE PIPING CONCEPTUAL ROUTING ONLY.
3. ALL ELECTRICAL AND PIPELINE RIGHT OF WAYS TO BE CONFIRMED DURING DETAILED DESIGN.
4. ELECTRICAL SUBSTATION SIZE AND LOCATION TO BE CONFIRMED DURING DETAILED DESIGN.
5. STATION PUMPHOUSE IS CONCEPTUAL ONLY, PIPING SIZES, ROUTING AND FOOTPRINT TO BE CONFIRMED DURING DETAILED DESIGN.
6. STATION FOOT PRINT SIZE 120 x 185m (2.22 HECTARES).
7. APPROXIMATE BUILDING SIZES
   ESB-1: 11m X 16.75m
   ESB-2: 11m X 16.75m
   PUMP HOUSE: 25.8m X 54.6m
   HAZARDOUS WASTE STORAGE: 3m X 4m
8. PRELIMINARY DRAWING TO BE FURTHER DELELOPED IN DETAILED DESIGN.

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	04 SEP 09 RTM	

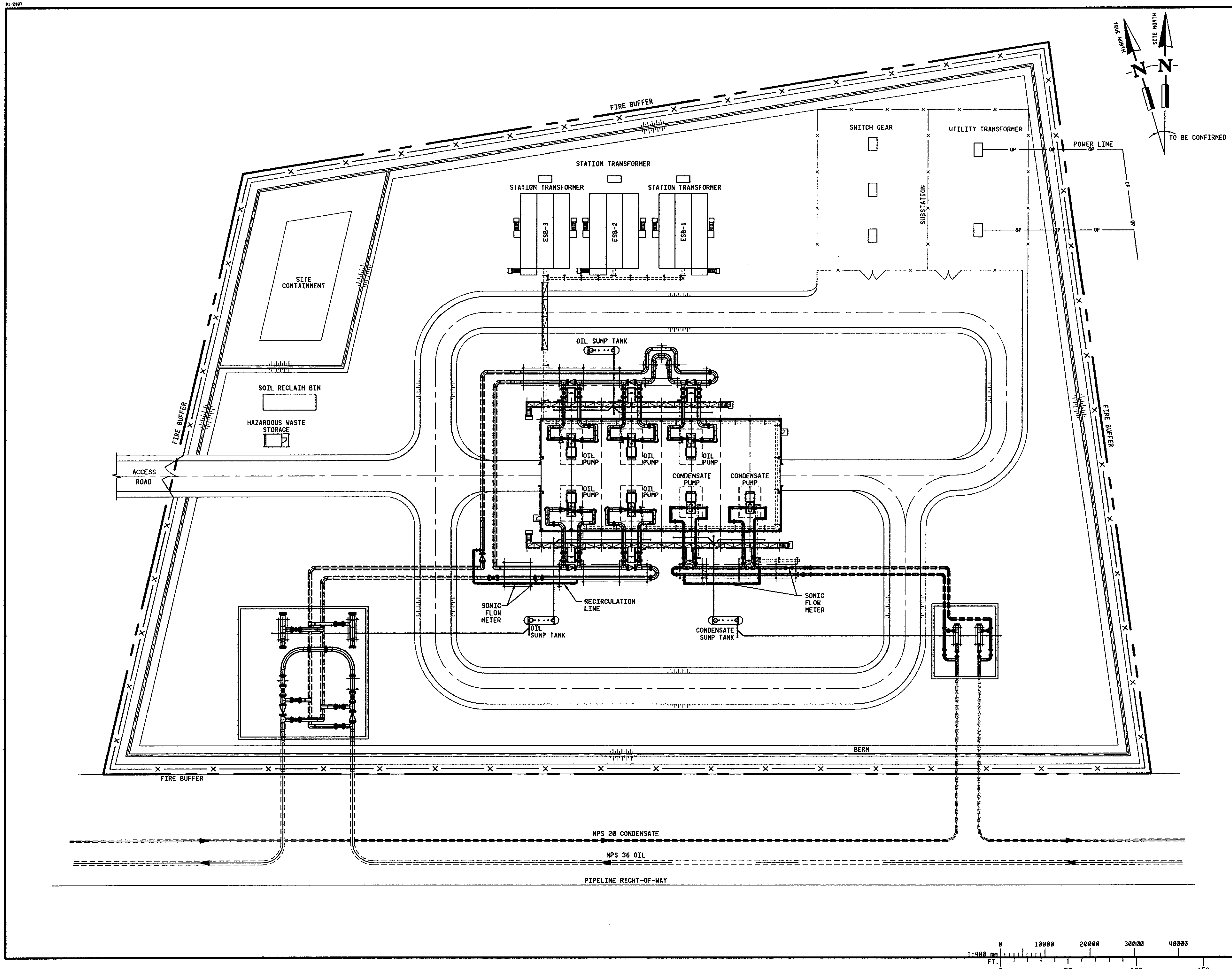
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
BRUDERHEIM STATION
OIL INITIATING PUMP STATION
PLOT PLAN

DRAWN	SEM	CHECK		APPROVE	
DATE	25 JAN 05	SCALE	1:400	APPROVE	

08C7138-SK-A-305 H-2



NOTES

1. SMALL BORE PIPING NOT SHOWN FOR CLARITY.
2. LARGE BORE PIPING CONCEPTUAL ROUTING ONLY.
3. ALL ELECTRICAL AND PIPELINE RIGHT OF WAYS TO BE CONFIRMED DURING DETAILED DESIGN.
4. ELECTRICAL SUBSTATION SIZE AND LOCATION TO BE CONFIRMED DURING DETAILED DESIGN.
5. STATION FOOT PRINT SIZE 3.1 HECTARES. TOTAL AREA REQUIRED INCLUDING FIRE BUFFER IS 3.1 HECTARES.
6. THE REQUIREMENT FOR PIG TRAP ASSEMBLIES AT THIS PUMP STATION WILL BE FINALIZED DURING DETAIL DESIGN.
7. WASHROOM FACILITIES AND SAFETY SHOWER LOCATION TO BE CONFIRMED IN DETAIL DESIGN.
8. RECLAMATION TOP SOIL TO BE STORED WITHIN FIRE BUFFER ZONE. TO BE CONFIRMED DURING DETAILED DESIGN.
9. APPROXIMATE BUILDING SIZES
   ESB-1: 11m X 16.75m
   ESB-2: 11m X 16.75m
   ESB-3: 11m X 16.75m
   PUMP HOUSE: 25.8m X 54.6m
   HAZARDOUS WASTE STORAGE: 3m X 4m
10. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

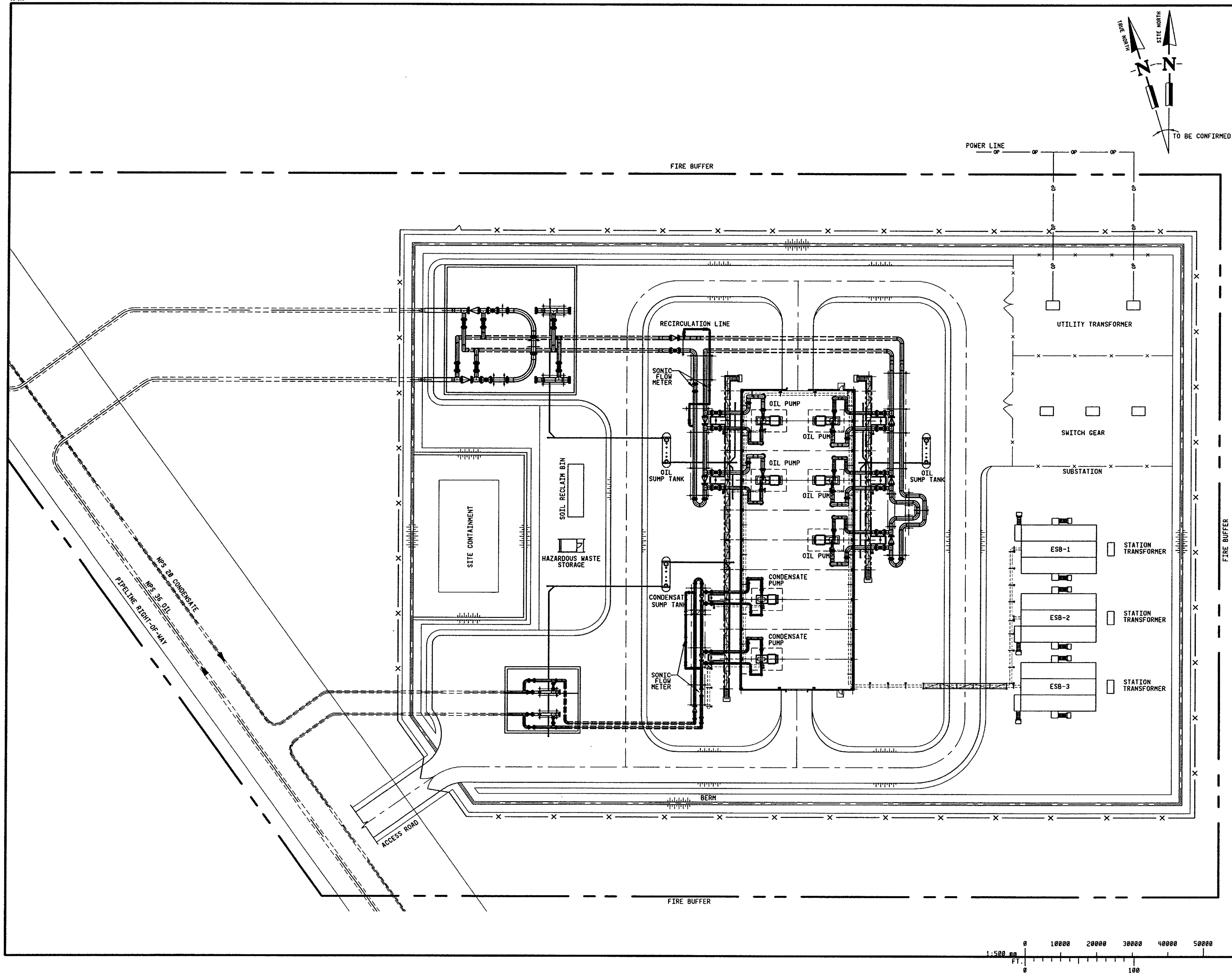
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
WHITECOURT STATION
DUAL PUMP STATION
PLOT PLAN

DRAWN JT	CHECK	APPROVE
DATE 23 OCT 08	SCALE 1:400	APPROVE

08C7138-SK-A-013 | H-3



NOTES

1. SMALL BORE PIPING NOT SHOWN FOR CLARITY.
2. LARGE BORE PIPING CONCEPTUAL ROUTING ONLY.
3. ALL ELECTRICAL AND PIPELINE RIGHT OF WAYS TO BE CONFIRMED DURING DETAILED DESIGN.
4. ELECTRICAL SUBSTATION SIZE AND LOCATION TO BE CONFIRMED DURING DETAILED DESIGN.
5. STATION FOOT PRINT SIZE 132.5 x 180m (2.37 HECTARES). TOTAL AREA REQUIRED INCLUDING FIRE BUFFER IS 4.25 HECTARES.
6. THE REQUIREMENT FOR PIG TRAP ASSEMBLIES AT THIS PUMP STATION WILL BE FINALIZED DURING DETAIL DESIGN.
7. WASHROOM FACILITIES AND SAFETY SHOWER LOCATION TO BE CONFIRMED IN DETAIL DESIGN.
8. RECLAMATION TOP SOIL TO BE STORED WITHIN FIRE BUFFER ZONE.
9. APPROXIMATE BUILDING SIZES
   ESB-1: 11m X 16.75m
   ESB-2: 11m X 16.75m
   ESB-3: 11m X 16.75m
   PUMP HOUSE: 25.8m X 68.1m
   HAZARDOUS WASTE STORAGE: 3m X 4m
10. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

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A	RE-ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

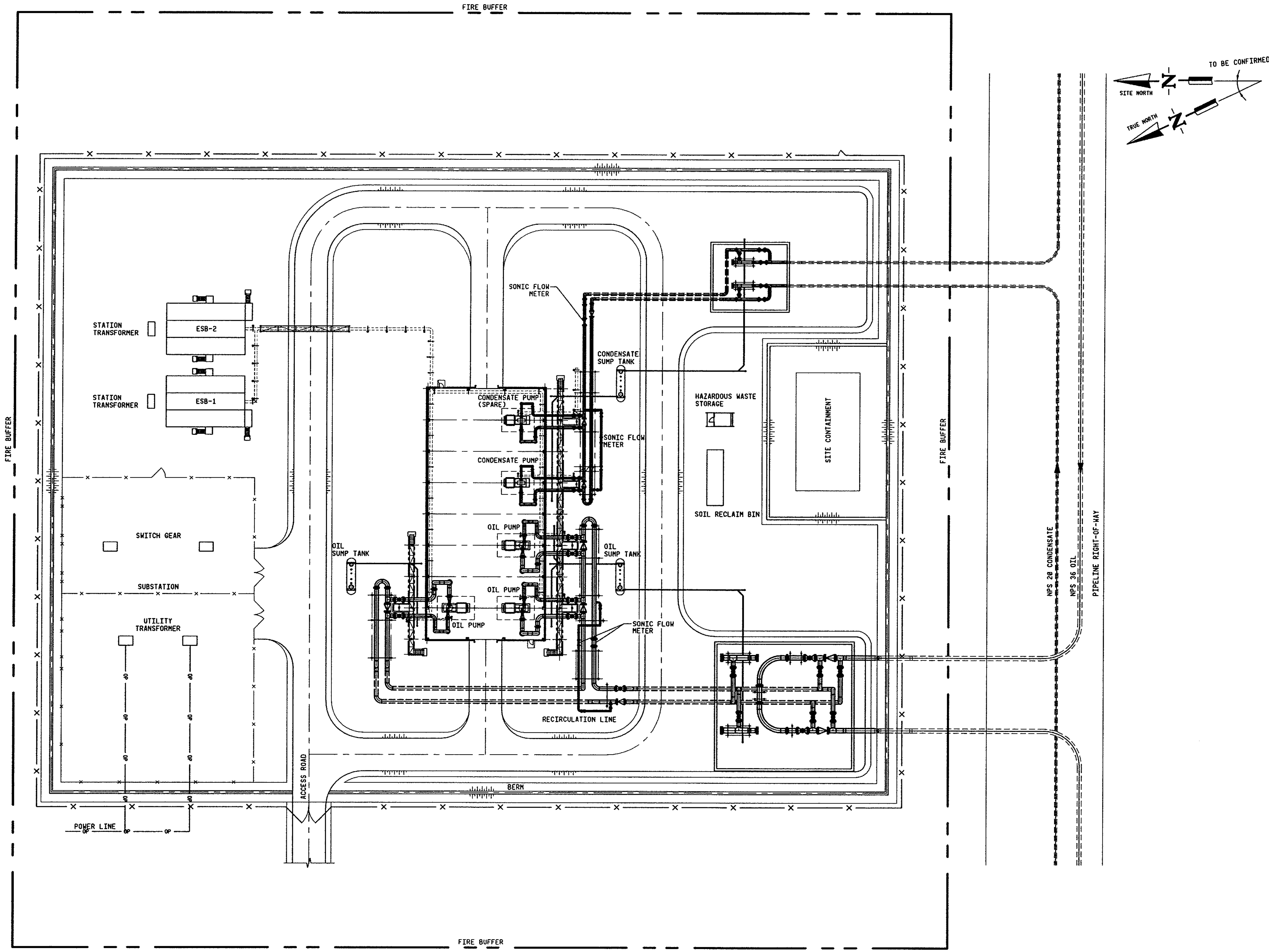
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
SMOKY RIVER STATION
DUAL PUMP STATION
PLOT PLAN

DRAWN	SEM	CHECK		APPROVE	
DATE	25 MAY 06	SCALE	1:500	APPROVE	

08C7138-SK-A-014 H-4



NOTES

1. SMALL BORE PIPING NOT SHOWN FOR CLARITY.
2. LARGE BORE PIPING CONCEPTUAL ROUTING ONLY.
3. ALL ELECTRICAL AND PIPELINE RIGHT OF WAYS TO BE CONFIRMED DURING DETAILED DESIGN.
4. ELECTRICAL SUBSTATION SIZE AND LOCATION TO BE CONFIRMED DURING DETAILED DESIGN.
5. STATION FOOT PRINT SIZE 140 x 185m (2.59 HECTARES). TOTAL AREA REQUIRED INCLUDING FIRE BUFFER IS 4.0 HECTARES.
6. THE REQUIREMENT FOR PIG TRAP ASSEMBLIES AT THIS PUMP STATION WILL BE FINALIZED DURING DETAIL DESIGN.
7. WASHROOM FACILITIES AND SAFETY SHOWER LOCATION TO BE CONFIRMED IN DETAIL DESIGN.
8. RECLAMATION TOP SOIL TO BE STORED WITHIN FIRE BUFFER ZONE.
9. APPROXIMATE BUILDING SIZES
   ESB-1: 11m X 16.75m
   ESB-2: 11m X 16.75m
   PUMP HOUSE: 25.8m X 54.6m
   HAZARDOUS WASTE STORAGE: 3m X 4m
10. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

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NO	REVISION	DATE/BY	APP
A	RE-ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

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FT. 0 50 100 150

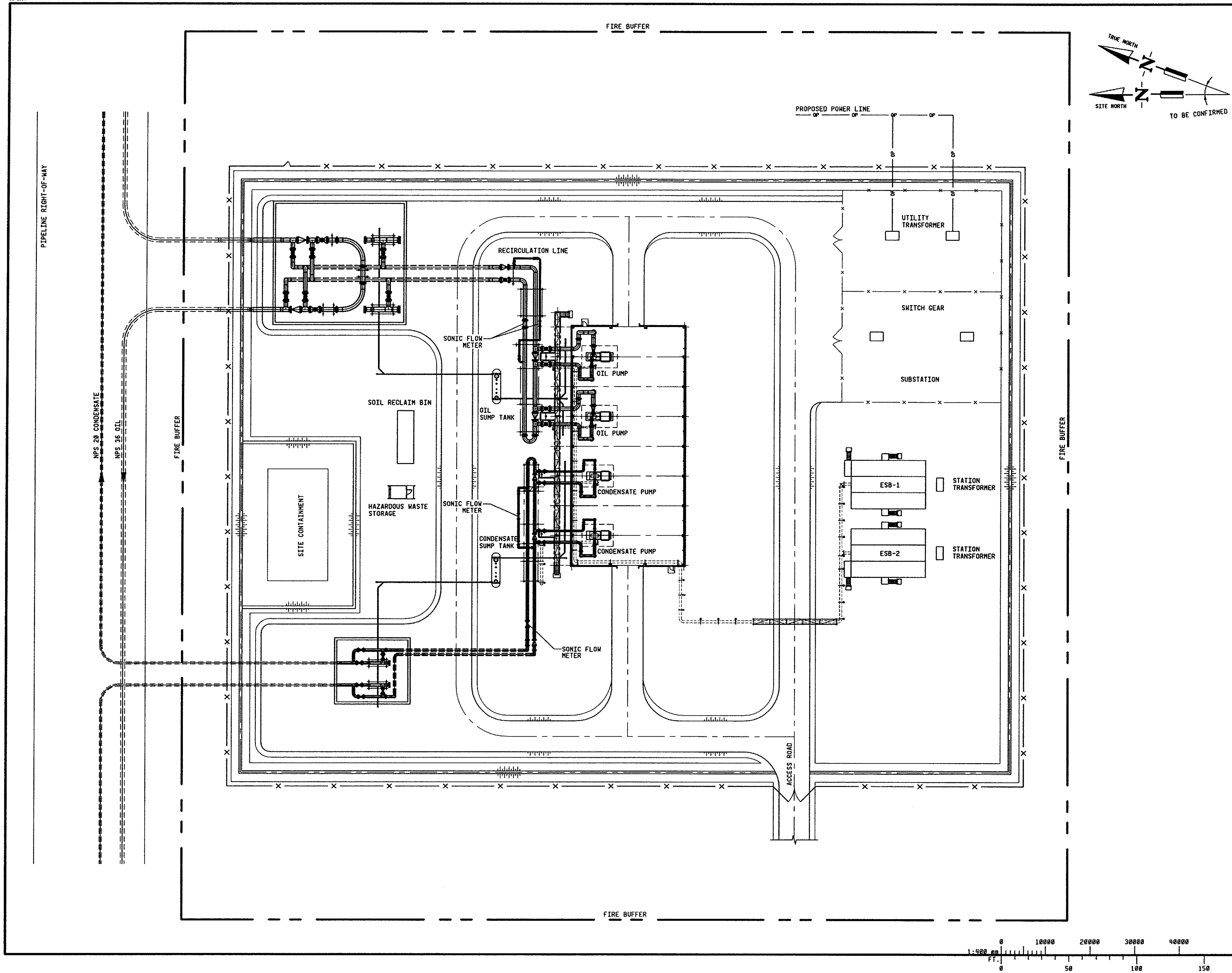
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
TUMBLER RIDGE STATION
DUAL PUMP STATION
PLOT PLAN

DRAWN SEM	CHECK	APPROVE
DATE 25 MAY 06	SCALE 1:400	APPROVE

08C7138-SK-A-015



NOTES

1. SMALL BORE PIPING NOT SHOWN FOR CLARITY.
2. LARGE BORE PIPING CONCEPTUAL ROUTING ONLY.
3. VERIFICATION OF ROAD RESTRICTIONS IN BC.
4. ALL ELECTRICAL AND PIPELINE RIGHT OF WAYS TO BE CONFIRMED DURING DETAILED DESIGN.
5. ELECTRICAL SUBSTATION SIZE AND LOCATION TO BE CONFIRMED DURING DETAILED DESIGN.
6. STATION FOOT PRINT SIZE 140 x 180m (2.52 HECTARES). TOTAL AREA REQUIRED INCLUDING FIRE BUFFER IS 4.0 HECTARES.
7. THE REQUIREMENT FOR PIG TRAP ASSEMBLIES AT THIS PUMP STATION WILL BE FINALIZED DURING DETAIL DESIGN.
8. WASHROOM FACILITIES AND SAFETY SHOWER LOCATION TO BE CONFIRMED IN DETAIL DESIGN.
9. RECLAMATION TOP SOIL TO BE STORED WITHIN FIRE BUFFER ZONE.
10. APPROXIMATE BUILDING SIZES
    ESB-1: 11m X 16.75m
    ESB-2: 11m X 16.75m
    PUMP HOUSE: 25.8m X 54.6m
    HAZARDOUS WASTE STORAGE: 3m X 4m
11. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

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NO	REVISION	DATE/BY	APP
A	RE-ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

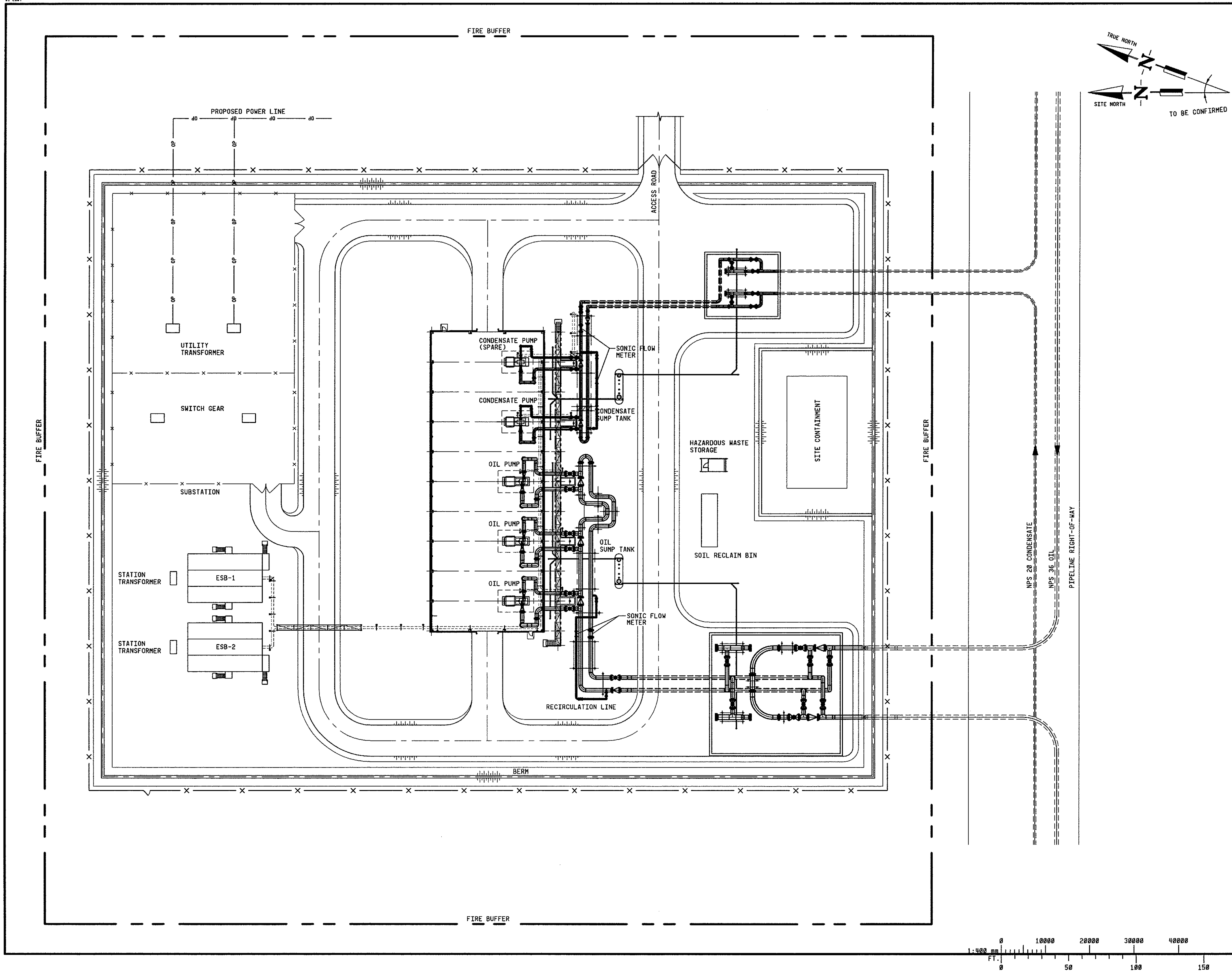
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
BEAR LAKE STATION
DUAL PUMP STATION
PLOT PLAN

DRAWN SEM	CHECK	APPROVE
DATE 13 APR 06	SCALE 1:400	APPROVE

08C7138-SK-A-011 H-6



NOTES

1. SMALL BORE PIPING NOT SHOWN FOR CLARITY.
2. LARGE BORE PIPING CONCEPTUAL ROUTING ONLY.
3. VERIFICATION OF ROAD RESTRICTIONS IN BC.
4. ALL ELECTRICAL AND PIPELINE RIGHT OF WAYS TO BE CONFIRMED DURING DETAILED DESIGN.
5. ELECTRICAL SUBSTATION SIZE AND LOCATION TO BE CONFIRMED DURING DETAILED DESIGN.
6. STATION FOOT PRINT SIZE 140 x 180m (2.52 HECTARES). TOTAL AREA REQUIRED INCLUDING FIRE BUFFER IS 4.0 HECTARES.
7. THE REQUIREMENT FOR PIG TRAP ASSEMBLIES AT THIS PUMP STATION WILL BE FINALIZED DURING DETAIL DESIGN.
8. WASHROOM FACILITIES AND SAFETY SHOWER LOCATION TO BE CONFIRMED IN DETAIL DESIGN.
9. RECLAMATION TOP SOIL TO BE STORED WITHIN FIRE BUFFER ZONE.
10. APPROXIMATE BUILDING SIZES
    ESB-1: 11m X 16.75m
    ESB-2: 11m X 16.75m
    PUMP HOUSE: 25.8m X 68.1m
    HAZARDOUS WASTE STORAGE: 3m X 4m
11. TRAP REQUIREMENTS TO BE CONFIRMED DURING DETAILED DESIGN.
12. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

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NO	REVISION	DATE/BY	APP
A	RE-ISSUED FOR NEB APPLICATION	04 SEP 09 RTM	

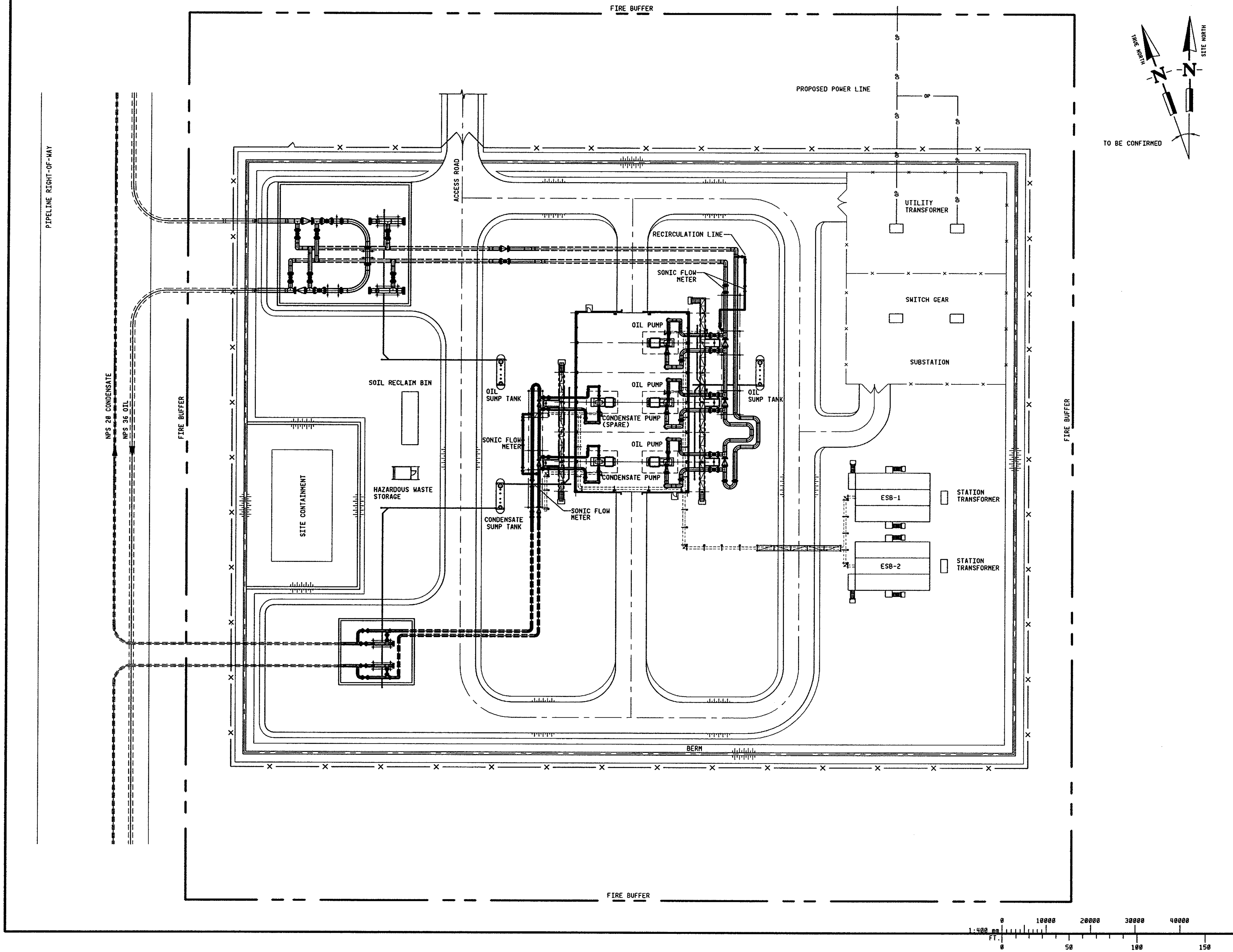
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
FORT ST. JAMES STATION
DUAL PUMP STATION
PLOT PLAN

DRAWN SEM	CHECK	APPROVE
DATE 25 MAY 06	SCALE 1:400	APPROVE

08C7138-SK-A-016 H-7



NOTES

1. SMALL BORE PIPING NOT SHOWN FOR CLARITY.
2. LARGE BORE PIPING CONCEPTUAL ROUTING ONLY.
3. VERIFICATION OF ROAD RESTRICTIONS IN BC.
4. ALL ELECTRICAL AND PIPELINE RIGHT OF WAYS TO BE CONFIRMED DURING DETAILED DESIGN.
5. ELECTRICAL SUBSTATION SIZE AND LOCATION TO BE CONFIRMED DURING DETAILED DESIGN.
6. STATION FOOT PRINT SIZE 140 x 180m (2.52 HECTARES). TOTAL AREA REQUIRED INCLUDING FIRE BUFFER IS 4.0 HECTARES.
7. THE REQUIREMENT FOR PIG TRAP ASSEMBLIES AT THIS PUMP STATION WILL BE FINALIZED DURING DETAIL DESIGN.
8. WASHROOM FACILITIES AND SAFETY SHOWER LOCATION TO BE CONFIRMED IN DETAIL DESIGN.
9. RECLAMATION TOP SOIL TO BE STORED WITHIN FIRE BUFFER ZONE.
10. APPROXIMATE BUILDING SIZES
    ESB-1: 11m X 16.75m
    ESB-2: 11m X 16.75m
    PUMP HOUSE: 25.8m X 54.6m
    HAZARDOUS WASTE STORAGE: 3m X 4m
11. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

Colt Engineering Corporation COLT

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	04 SEP 09 RTM	

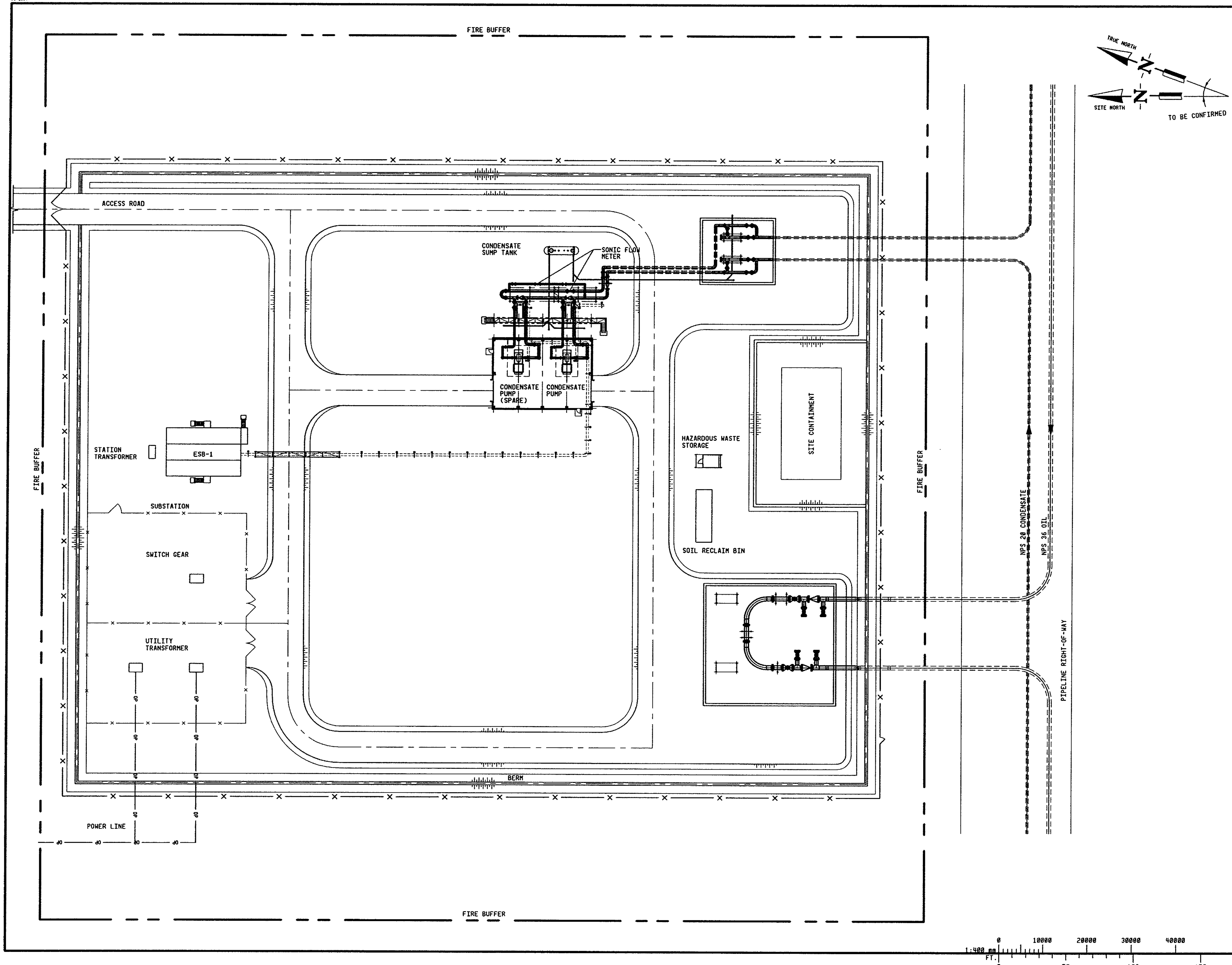
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
BURNS LAKE STATION
DUAL PUMP STATION
PLOT PLAN

DRAWN SEM	CHECK	APPROVE
DATE 13 AUG 06	SCALE 1:400	APPROVE

08C7138-SK-A-012 | H-8



NOTES

1. SMALL BORE PIPING NOT SHOWN FOR CLARITY.
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3. VERIFICATION OF ROAD RESTRICTIONS IN BC.
4. ALL ELECTRICAL AND PIPELINE RIGHT OF WAYS TO BE CONFIRMED DURING DETAILED DESIGN.
5. ELECTRICAL SUBSTATION SIZE AND LOCATION TO BE CONFIRMED DURING DETAILED DESIGN.
6. STATION FOOT PRINT SIZE 185 x 144.35m (2.8 HECTARES). TOTAL AREA REQUIRED INCLUDING FIRE BUFFER IS 4.0 HECTARES.
7. THE REQUIREMENT FOR PIG TRAP ASSEMBLIES AT THIS PUMP STATION WILL BE FINALIZED DURING DETAIL DESIGN.
8. WASHROOM FACILITIES AND SAFETY SHOWER LOCATION TO BE CONFIRMED IN DETAIL DESIGN.
9. RECLAMATION TOP SOIL TO BE STORED WITHIN FIRE BUFFER ZONE.
10. APPROXIMATE BUILDING SIZES
    ESB-1: 11m X 16.75m
    CONDENSATE PUMP HOUSE: 16.2m X 22.6m
    HAZARDOUS WASTE STORAGE: 3m X 4m
11. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

Colt Engineering Corporation

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(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	RE-ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

NO	REVISION	DATE/BY	APPROVE

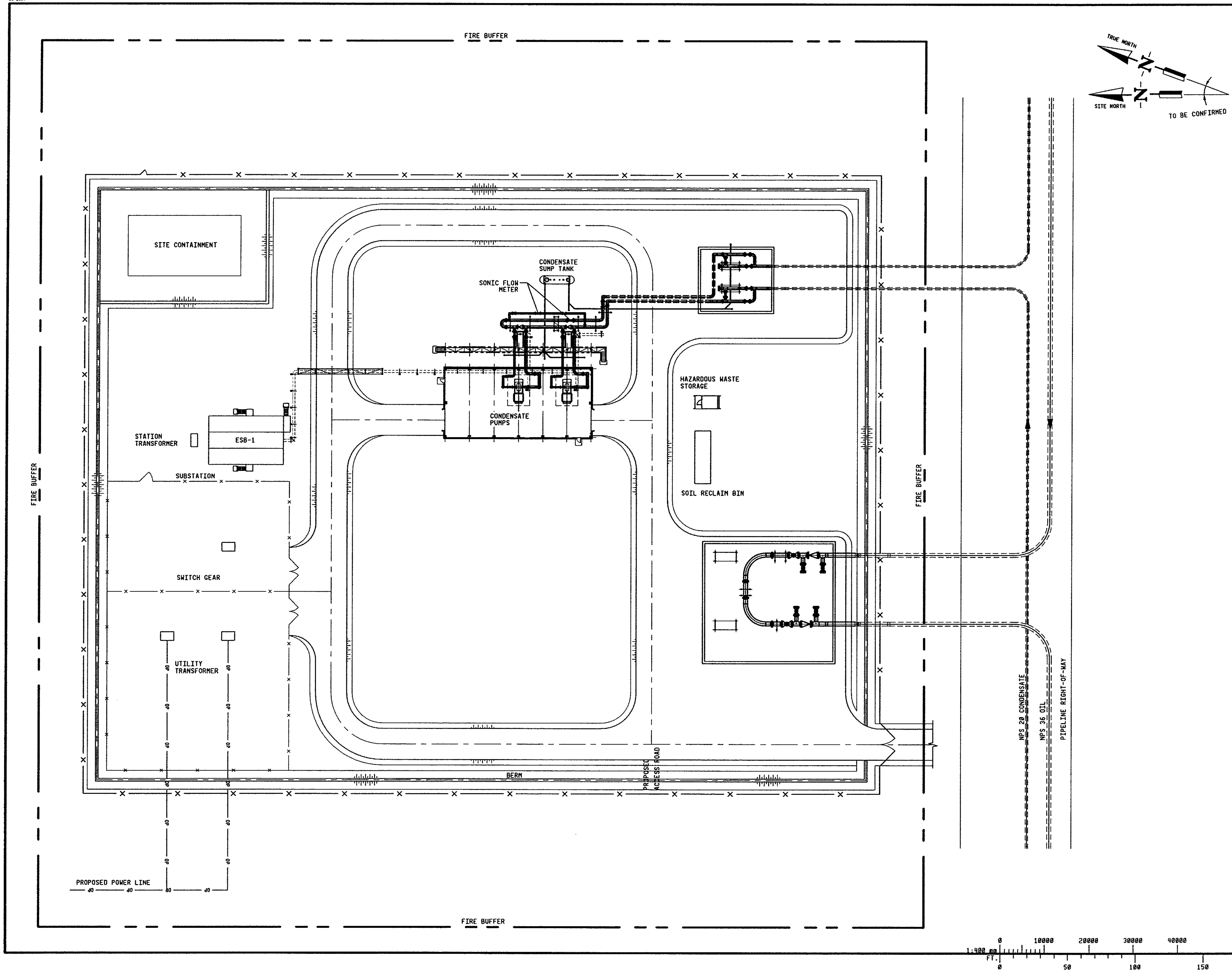
ENBRIDGE
NORTHERN
GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
HOUSTON STATION
CONDENSATE PUMP STATION WITH SCRAPER TRAPS
PLOT PLAN

DRAWN	WK	CHECK		APPROVE	
DATE	18 AUG 05	SCALE	1:400	APPROVE	

08C7138-SK-A-003

H-9



NOTES

1. SMALL BORE PIPING NOT SHOWN FOR CLARITY.
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4. ALL ELECTRICAL AND PIPELINE RIGHT OF WAYS TO BE CONFIRMED DURING DETAILED DESIGN.
5. ELECTRICAL SUBSTATION SIZE AND LOCATION TO BE CONFIRMED DURING DETAILED DESIGN.
6. STATION FOOT PRINT SIZE 180 x 140m (2.52 HECTARES). TOTAL AREA REQUIRED INCLUDING FIRE BUFFER IS 4.0 HECTARES.
7. THE REQUIREMENT FOR PIG TRAP ASSEMBLIES AT THIS PUMP STATION WILL BE FINALIZED DURING DETAIL DESIGN.
8. WASHROOM FACILITIES AND SAFETY SHOWER LOCATION TO BE CONFIRMED IN DETAIL DESIGN.
9. RECLAMATION TOP SOIL TO BE STORED WITHIN FIRE BUFFER ZONE.
10. APPROXIMATE BUILDING SIZES
    ESB-1: 11m X 16.75m
    CONDENSATE PUMP HOUSE: 16.2m X 33.6m
    HAZARDOUS WASTE STORAGE: 3m X 4m
11. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
M	RE-ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

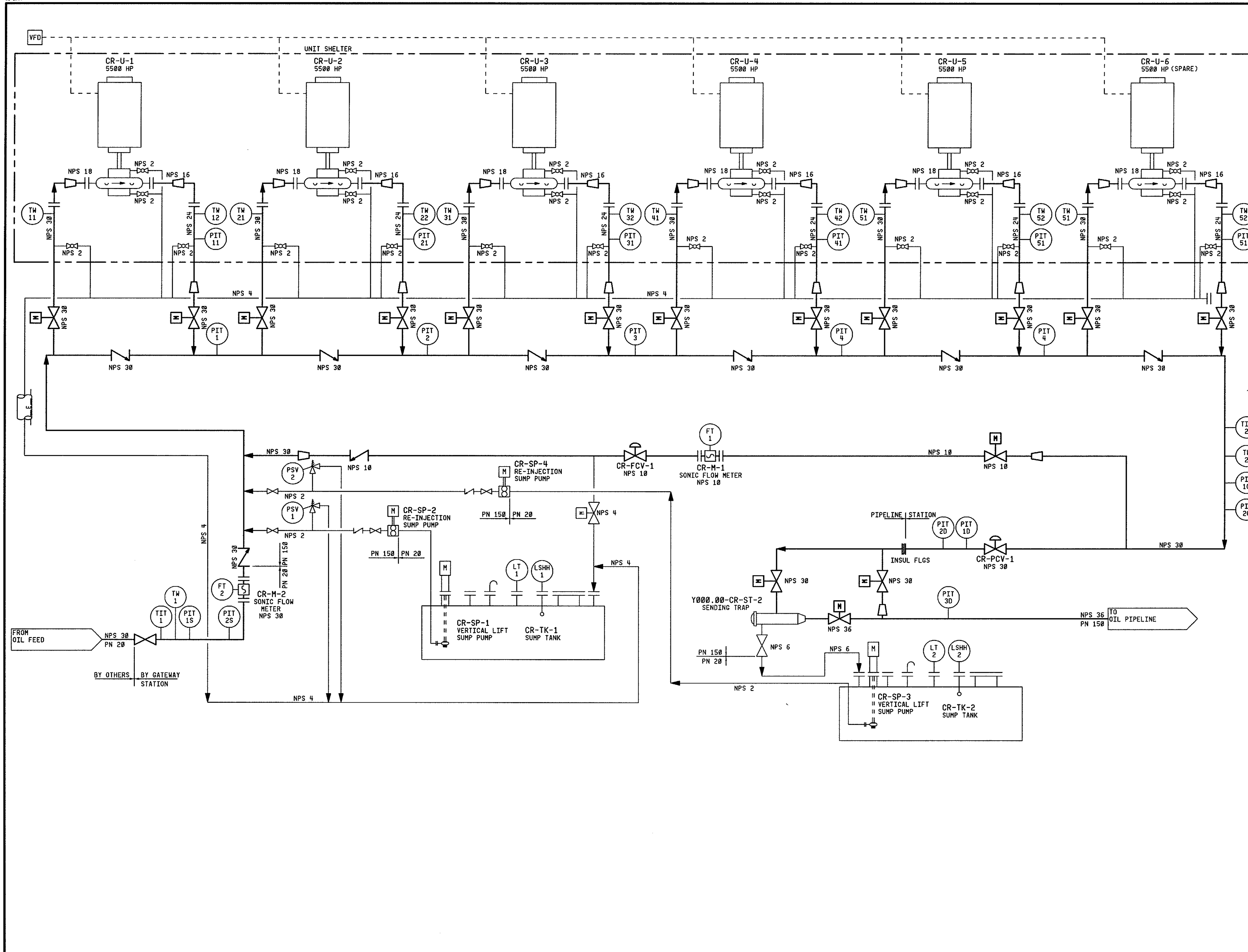
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
CLEARWATER STATION
CONDENSATE PUMP STATION WITH SCRAPER TRAPS
PLOT PLAN

DRAWN SEM	CHECK	APPROVE
DATE 24 MAY 06	SCALE 1:400	APPROVE

08C1738-SK-A-017 | H-10



NOTES:

1. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "CR-".
2. FUNCTIONAL SYSTEM CODE CR- INDICATES OIL MAINLINE.
3. LOCATION CODE FOR ALL REMAINGING INSTRUMENTS, EQUIPMENT, ETC. IS "BR" FOR bRUDERHEIM.
4. EACH PUMP AND PUMP MOTOR UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
5. EACH PUMP UNIT SHELTER INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, AND AMBIENT TEMPERATURE MONITOR.
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7. STATION LOCATION AND NUMBER OF PUMPS ARE BASED ON ENBRIDGE HYDRAULICS SUPPLIED JUNE 2008.
8. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
9. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
J	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

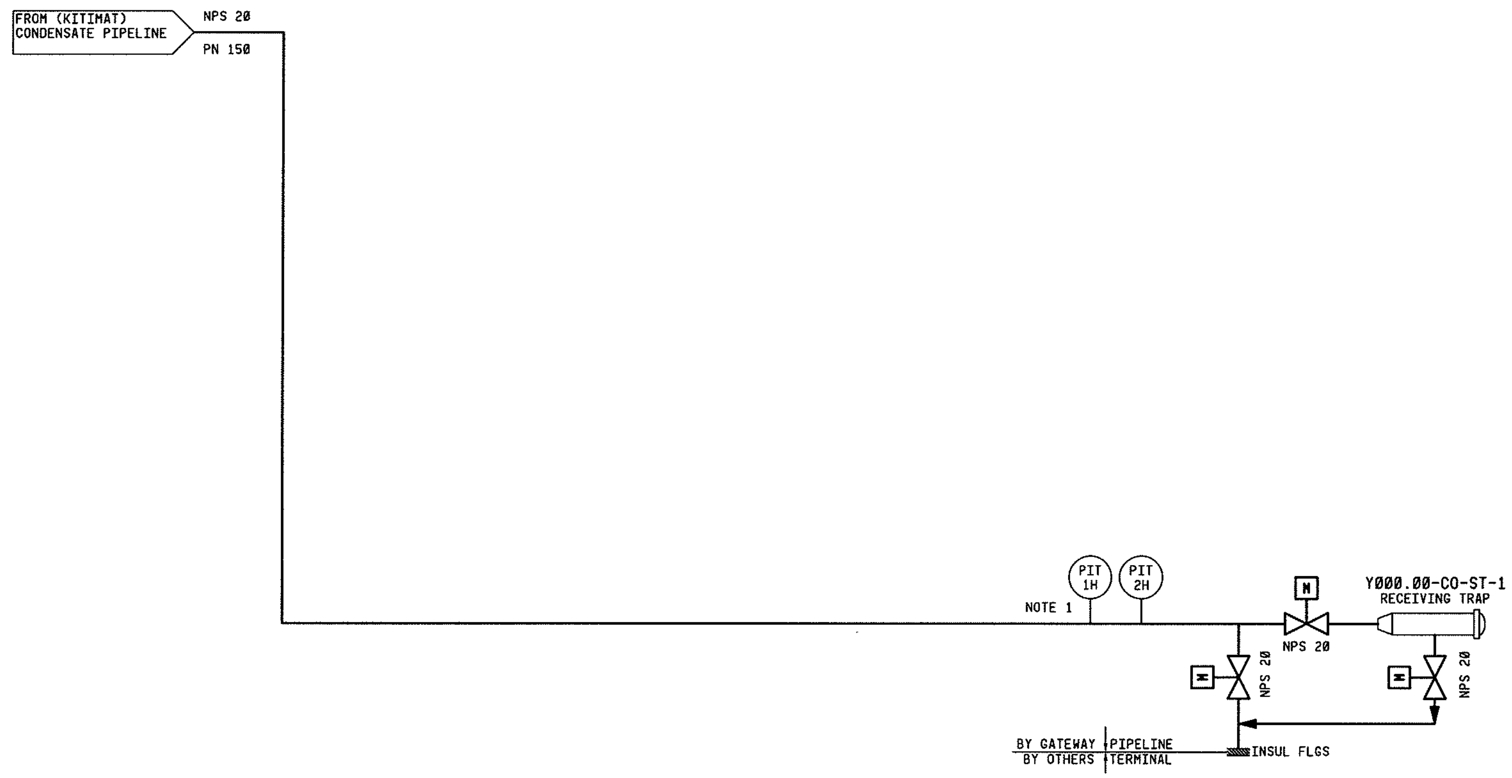
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
BRUDERHEIM STATION
OIL INITIATING PUMPS
PROCESS FLOW DIAGRAM

DRAWN RM	CHECK	APPROVE	
DATE 07 NOV 06	SCALE NTS	APPROVE	

08C7138-SK-B-302 | H-11



NOTES:

1. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "CO-".
2. FUNCTIONAL SYSTEM CODE CO- INDICATES CONDENSATE MAINLINE.
3. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "BR-" FOR BRUDERHEIM.
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HOLDS:

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
J	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

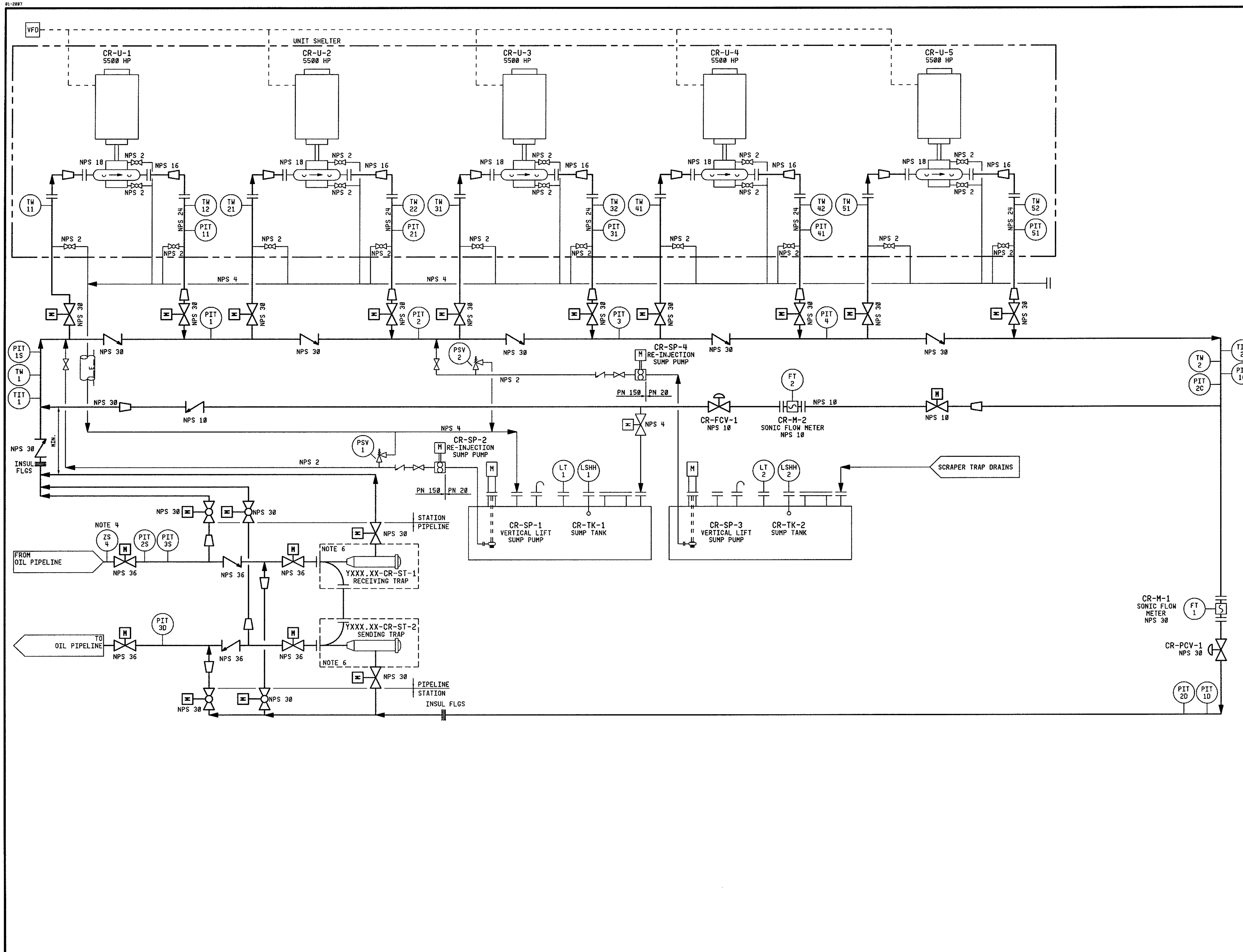
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
BRUDERHEIM STATION
CONDENSATE RECEIVING TRAP
PROCESS FLOW DIAGRAM

DRAWN RM	CHECK	APPROVE	
DATE 07 NOV 06	SCALE	APPROVE	

08C7138-SK-B-350 | H-12



NOTES:

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3. FUNCTIONAL SYSTEM CODE CR- INDICATES OIL MAINLINE.
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HOLDS:

1. STATION KP AND ASSOCIATED LOCATION CODE.

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
1	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

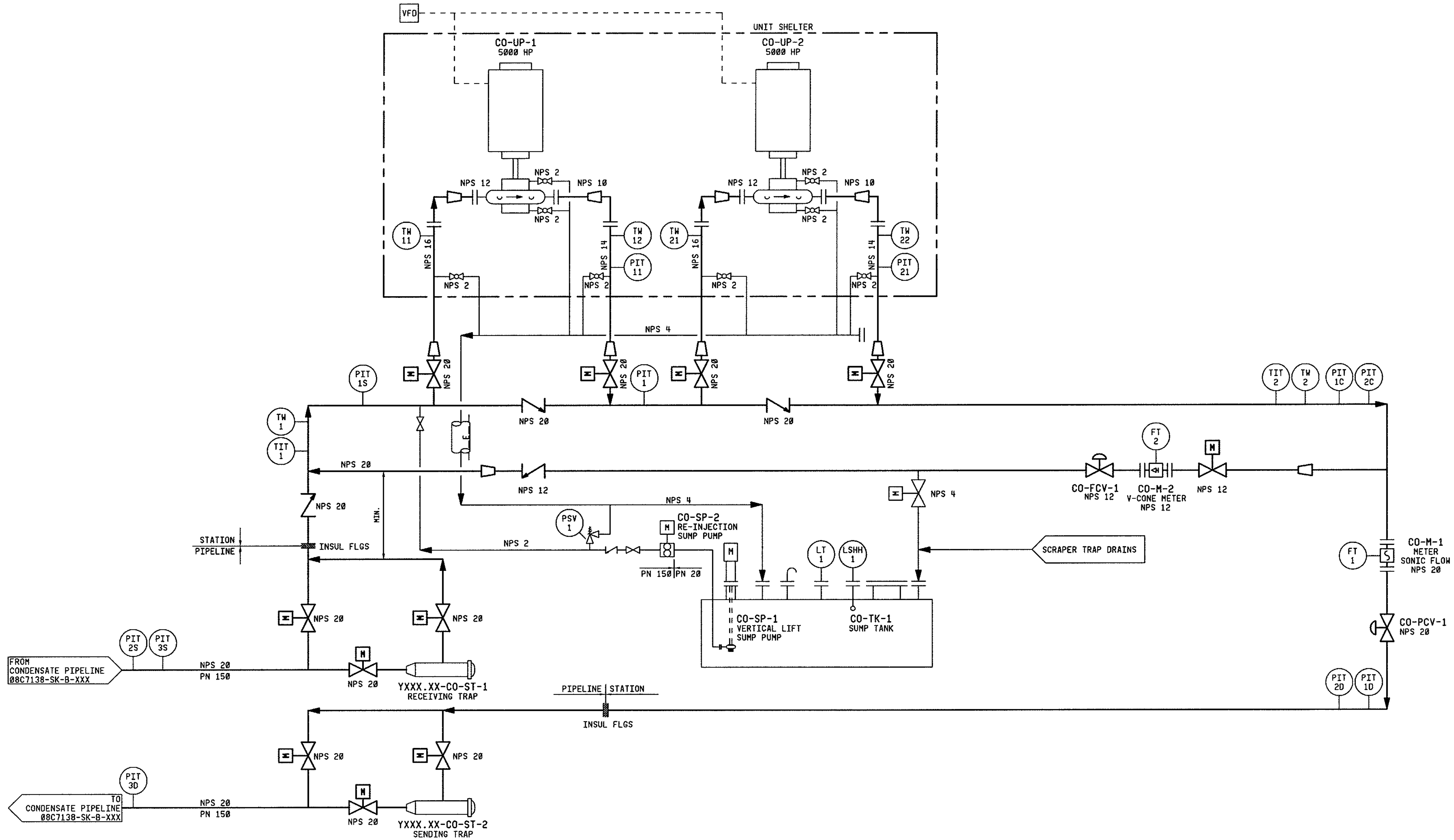
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
WHITECOURT STATION
OIL PUMPS
PROCESS FLOW DIAGRAM

DRAWN	RM	CHECK		APPROVE	
DATE	07 NOV 06	SCALE	NTS	APPROVE	

08C7138-SK-B-109



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Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

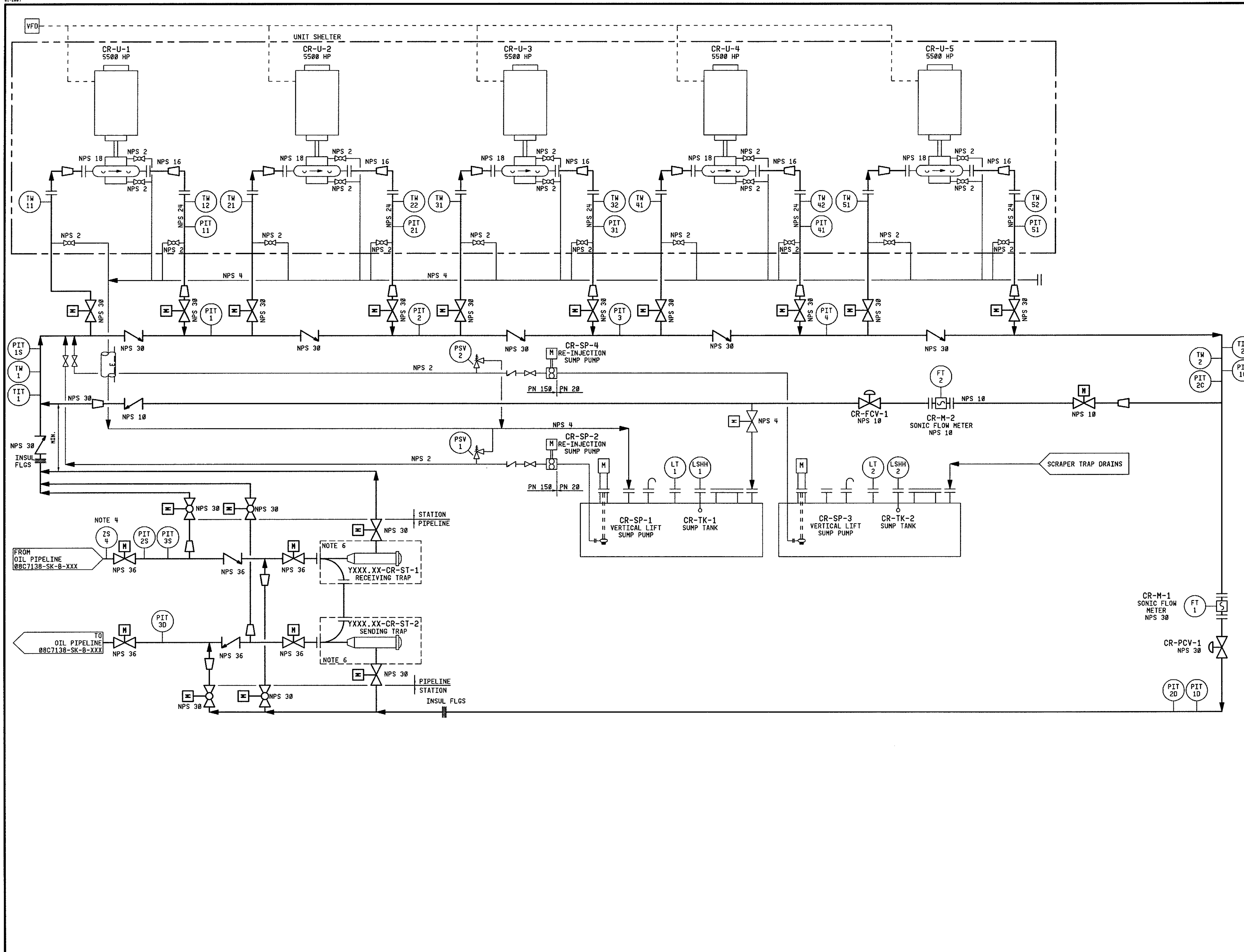
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
WHITECOURT STATION
CONDENSATE PUMPS
PROCESS FLOW DIAGRAM

DRAWN	RM	CHECK		APPROVE	
DATE	07 NOV 06	SCALE	NTS	APPROVE	

08C7138-SK-B-172 H-14



NOTES:

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Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
L	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

NO	REVISION	DATE/BY	APPROVE

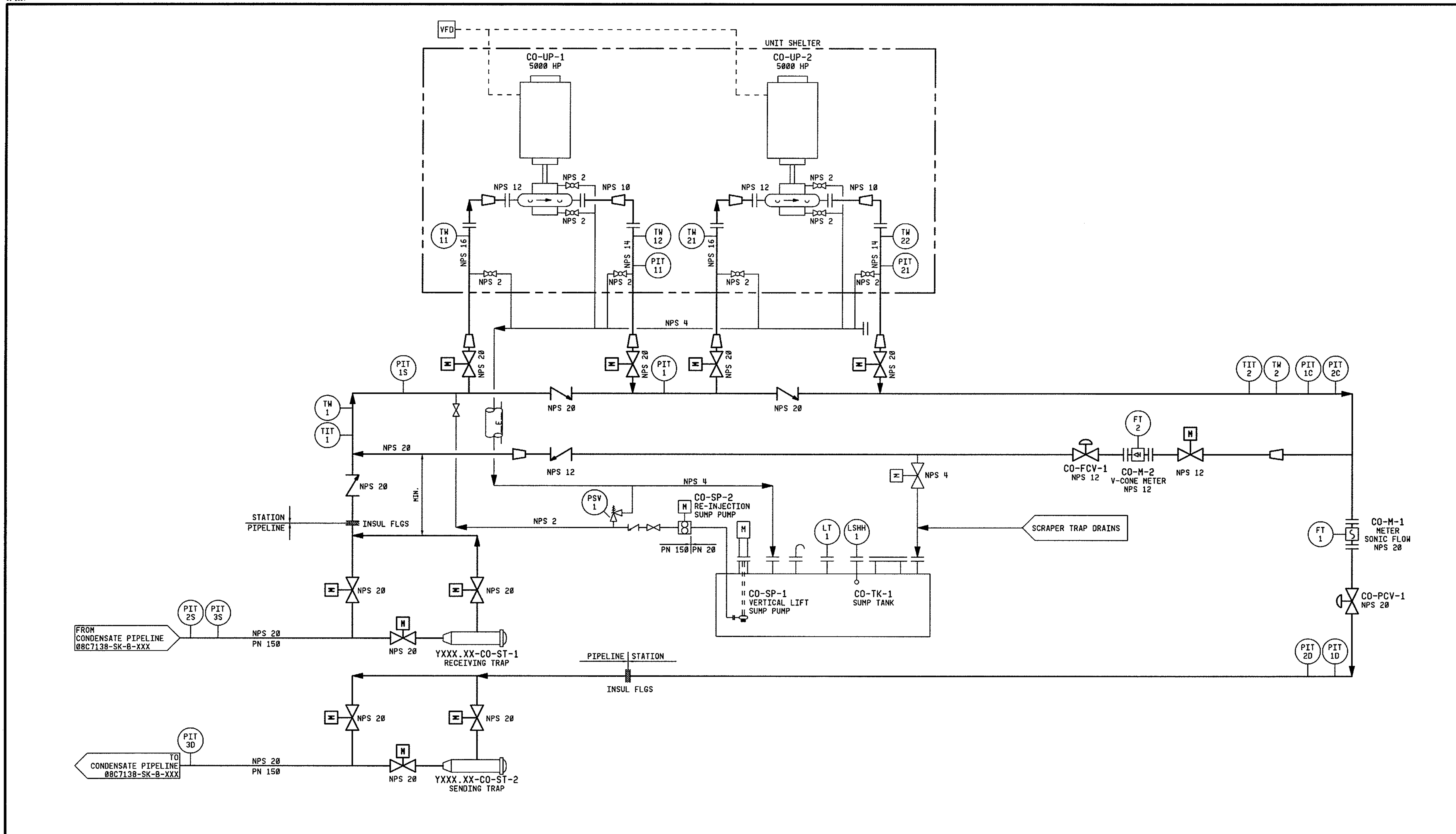
ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
SMOKY RIVER STATION
OIL PUMPS
PROCESS FLOW DIAGRAM

DRAWN RM	CHECK	APPROVE
DATE 07 NOV 06	SCALE NTS	APPROVE

08C7138-SK-B-113

H-15



NOTES:

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HOLDS:

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Colt Engineering Corporation

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(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

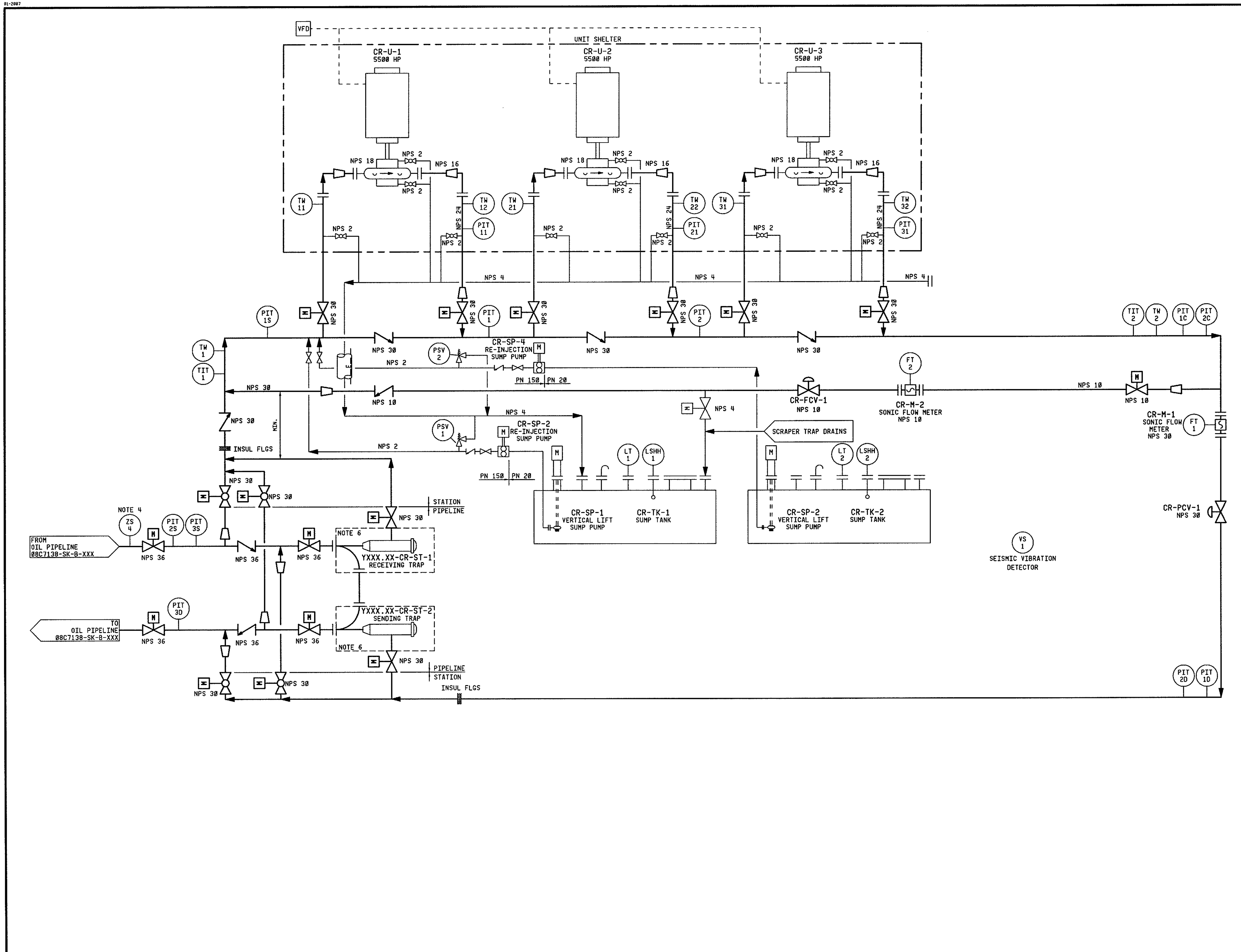
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
SMOKY RIVER STATION
CONDENSATE PUMPS
PROCESS FLOW DIAGRAM

DRAWN	RM	CHECK	APPROVE
DATE	07 NOV 06	SCALE NTS	APPROVE

08C7138-SK-B-173 H-16



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HOLDS:

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Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

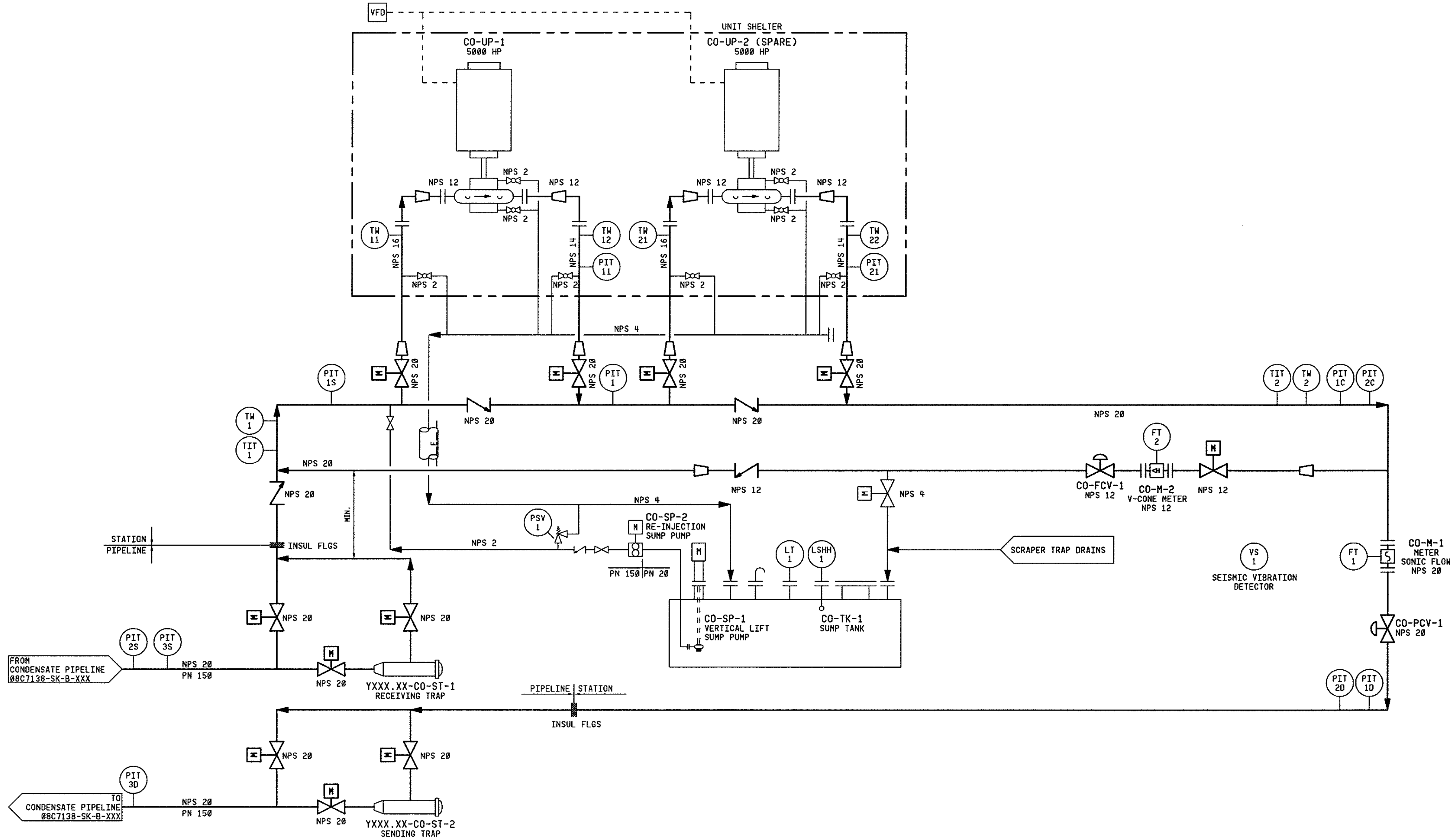
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
TUMBLER RIDGE STATION
OIL PUMPS
PROCESS FLOW DIAGRAM

DRAWN	RM	CHECK		APPROVE	
DATE	07 NOV 06	SCALE	NTS	APPROVE	

08C7138-SK-B-114



NOTES:

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HOLDS:

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Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

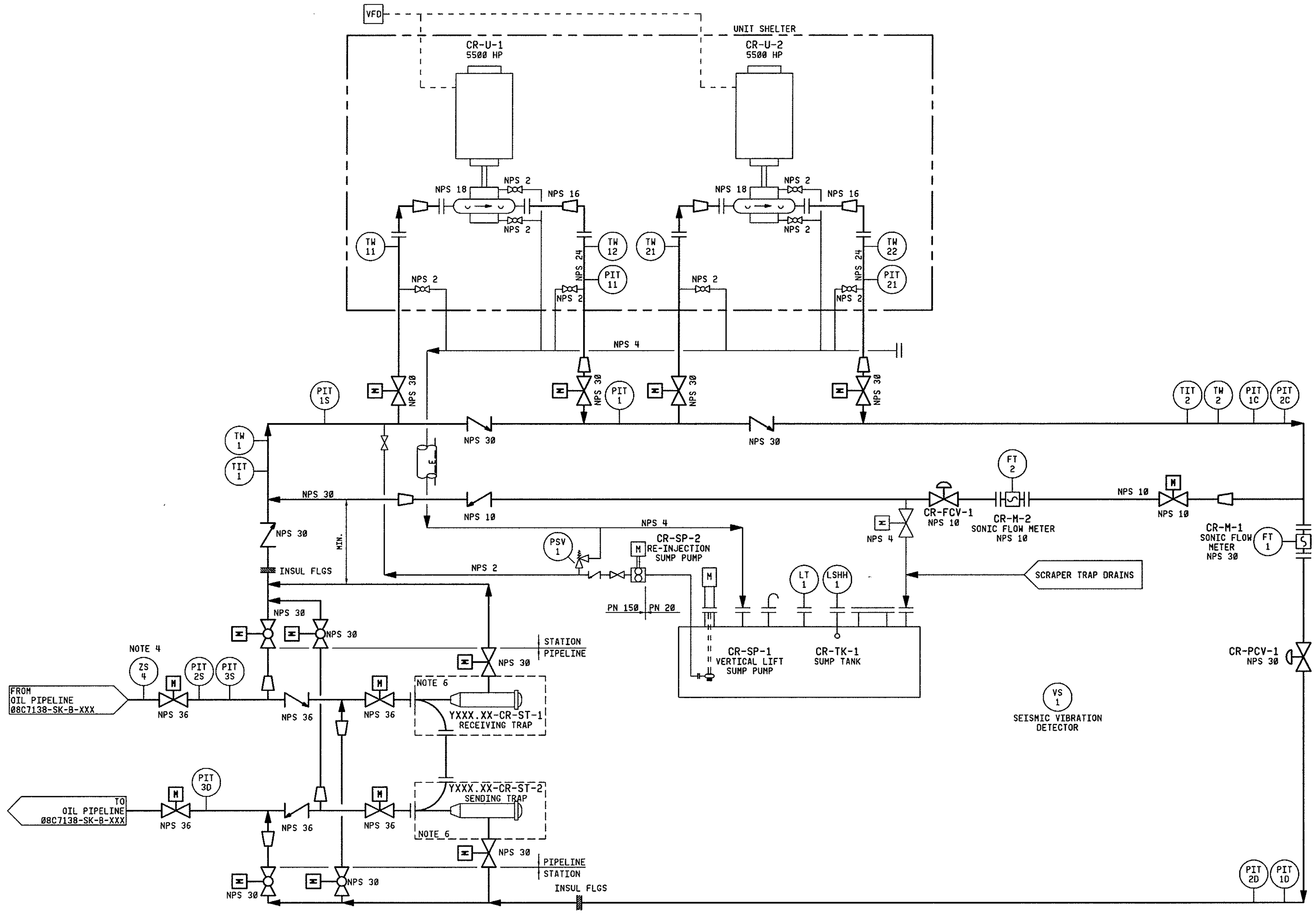
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
TUMBLER RIDGE STATION
CONDENSATE PUMPS
PROCESS FLOW DIAGRAM

DRAWN	RM	CHECK		APPROVE	
DATE	07 NOV 06	SCALE	NTS	APPROVE	

08C7138-SK-B-174 | H-18



NOTES:

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Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

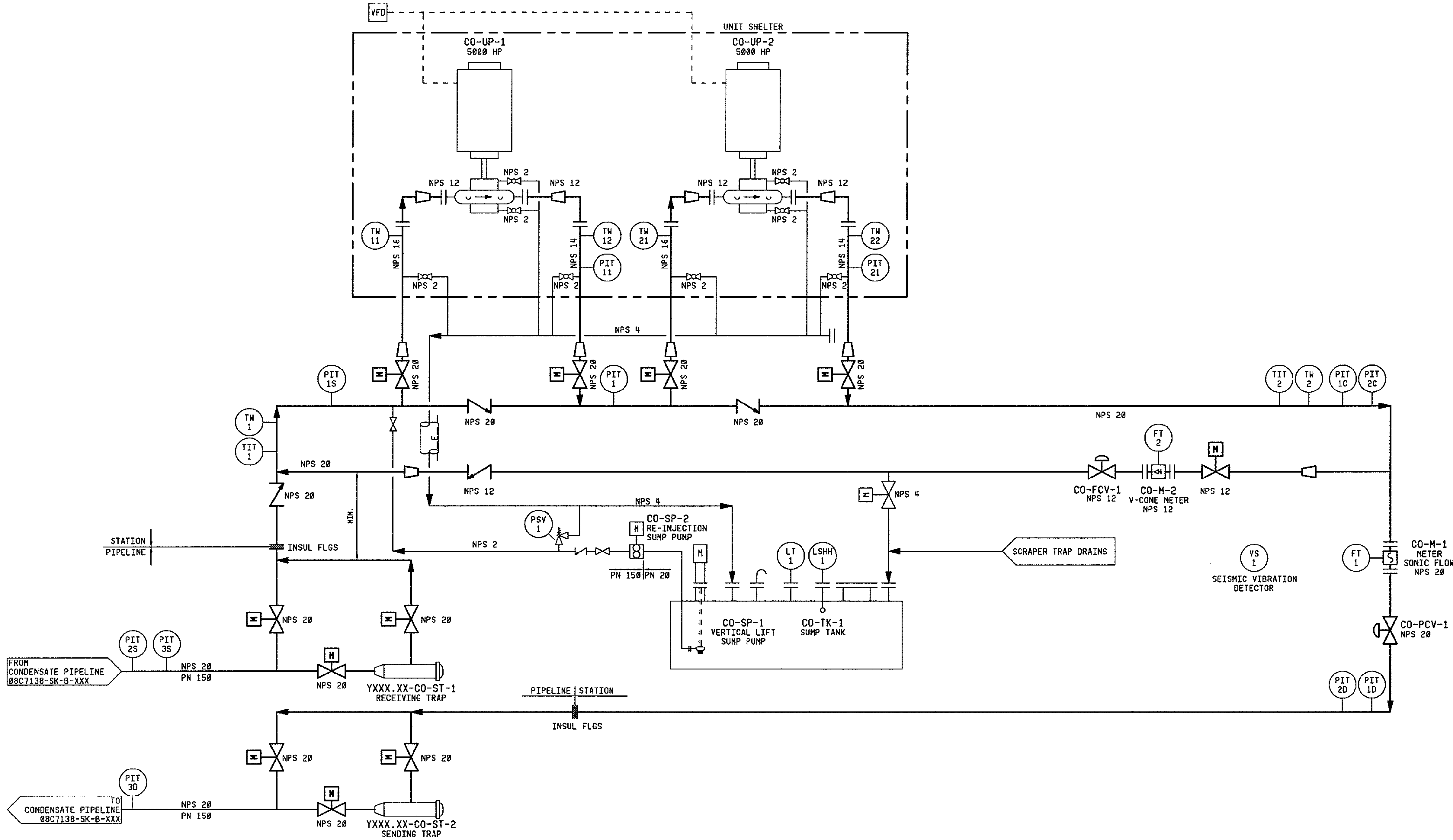
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
BEAR LAKE STATION
OIL PUMPS
PROCESS FLOW DIAGRAM

DRAWN	RM	CHECK		APPROVE	
DATE	07 NOV 06	SCALE	NTS	APPROVE	

08C7138-SK-B-117 | H-19



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Colt Engineering Corporation

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(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

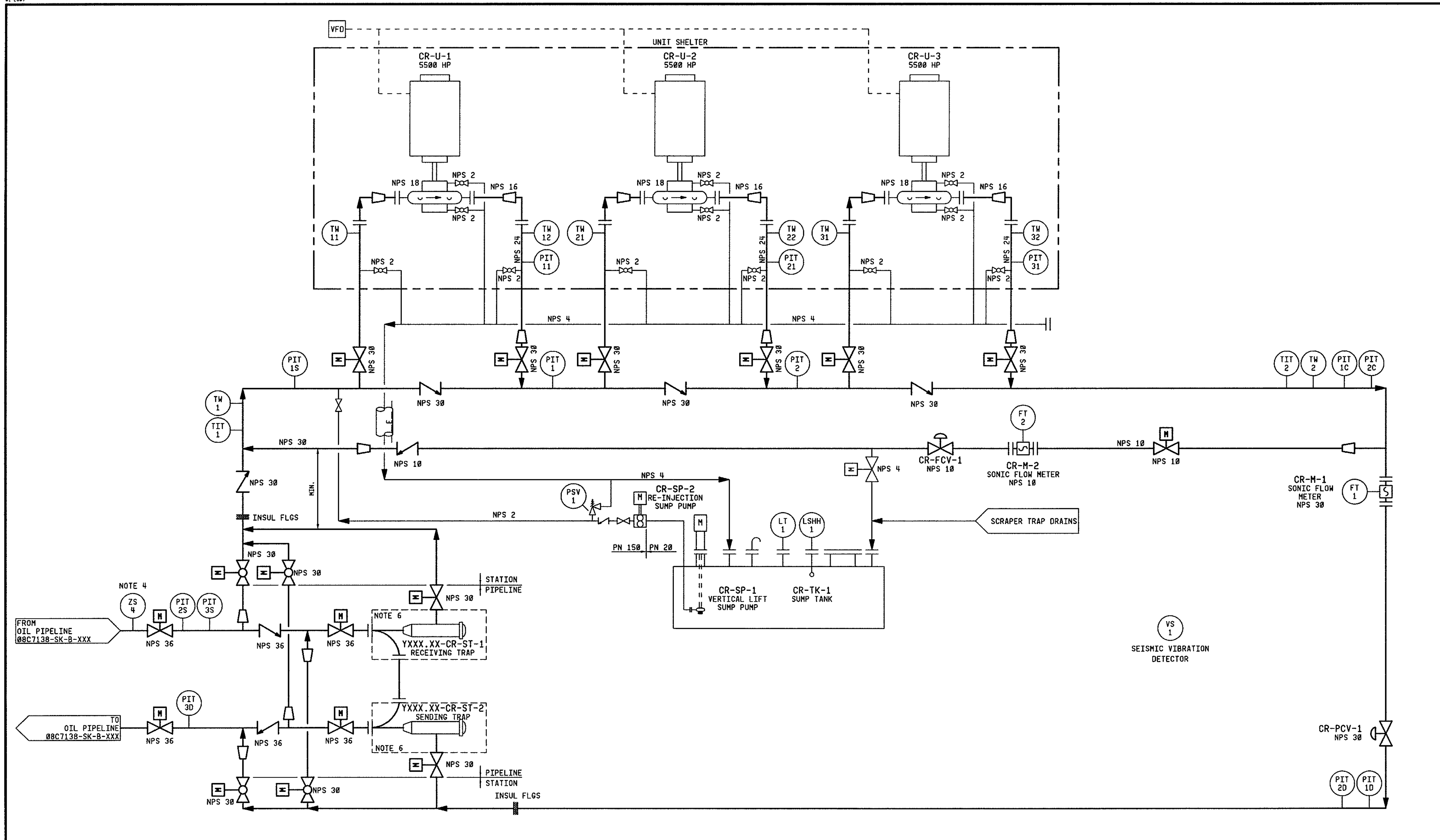
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
BEAR LAKE STATION
CONDENSATE PUMPS
PROCESS FLOW DIAGRAM

DRAWN RM	CHECK	APPROVE
DATE 07 NOV 06	SCALE NTS	APPROVE

08C7138-SK-B-154 | H-20



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Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

NO	REVISION	DATE/BY	APPROVE

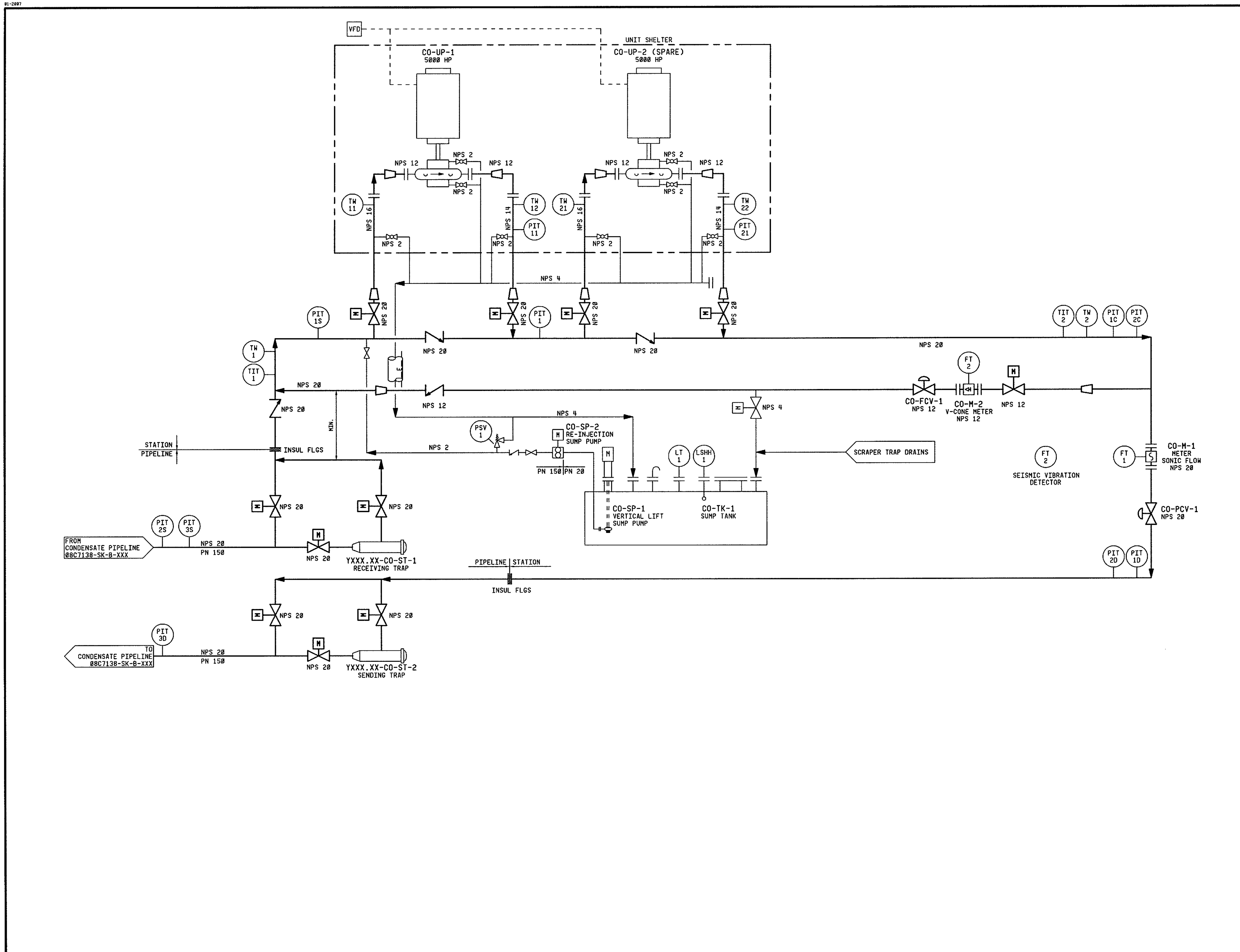
ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
FORT ST. JAMES STATION
OIL PUMPS
PROCESS FLOW DIAGRAM

DRAWN	RM	CHECK		APPROVE	
DATE	07 NOV 06	SCALE	NTS	APPROVE	

08C7138-SK-B-115 H-21

01-2007



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Colt Engineering Corporation

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(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

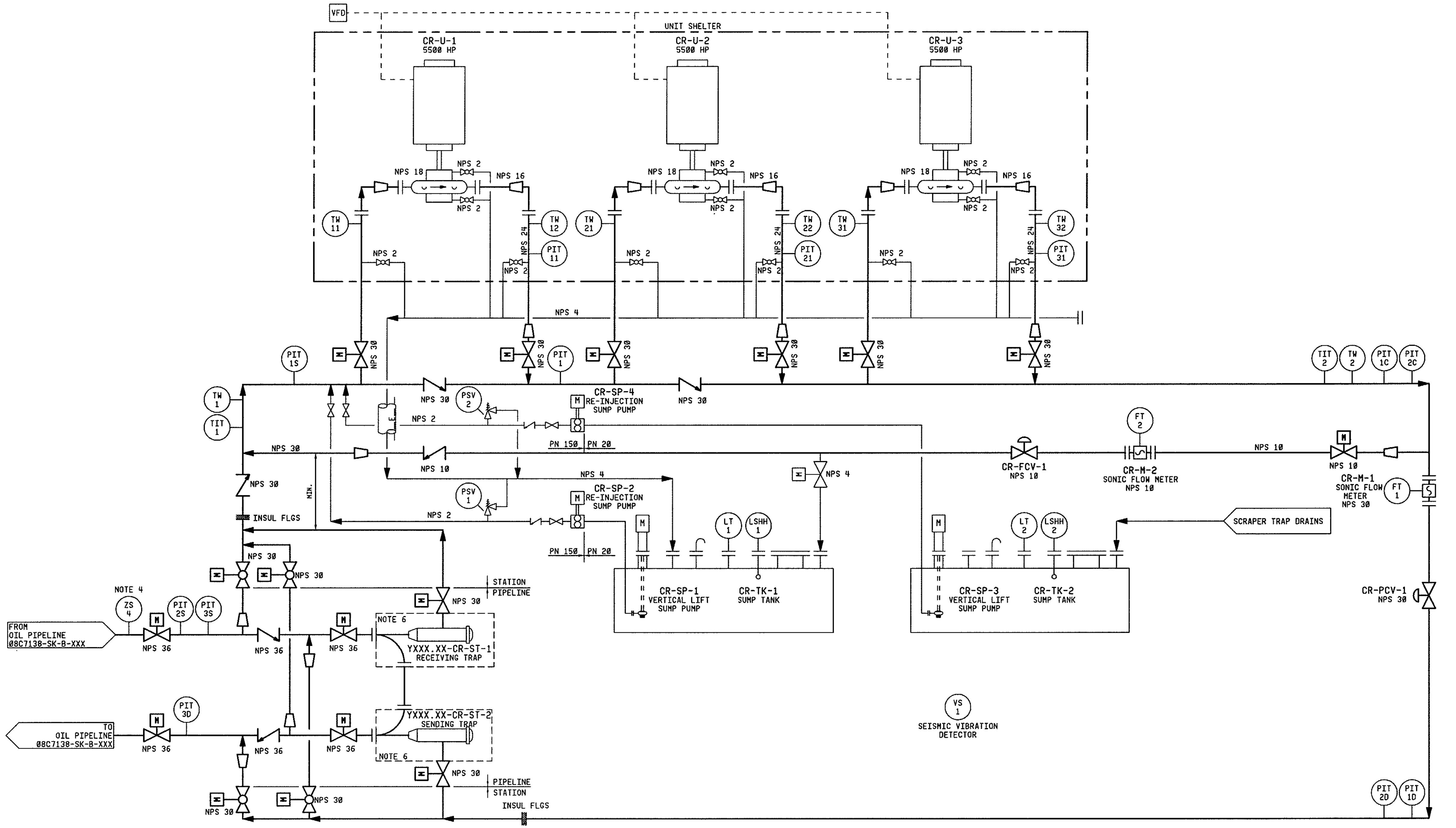
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
FORT ST. JAMES STATION
CONDENSATE PUMPS
PROCESS FLOW DIAGRAM

DRAWN	RM	CHECK		APPROVE	
DATE	07 NOV 06	SCALE	NTS	APPROVE	

08C7138-SK-B-175 | H-22



NOTES:

1. ALL PIPING PN 150 UNLESS NOTED OTHERWISE.
2. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "CR-".
3. FUNCTIONAL SYSTEM CODE CR- INDICATES OIL MAINLINE.
4. LOCATION CODE FOR REMOTE PIG POSITION SWITCH IS "YXXX.XX".
5. LOCATION CODE FOR ALL REMAINING INSTRUMENTS, EQUIPMENT ETC. IS "YXXX.XX".
6. WHEN PIG TRAPS ARE REQUIRED A TEMPORARY SPOOL IS INSTALLED IN NOTED LOCATION.
7. EACH PUMP AND PUMP MOTOR UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
8. EACH PUMP UNIT SHELTER INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, AND AMBIENT TEMPERATURE MONITOR.
9. BUILDINGS AND CONFINED SPACES ARE EQUIPPED WITH A HEAT DETECTOR, SMOKE DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
10. STATION LOCATION AND NUMBER OF PUMPS ARE BASED ON ENBRIDGE HYDRAULICS SUPPLIED JUNE 2008.
11. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
12. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

1. STATION KP AND ASSOCIATED LOCATION CODE.

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

NO	REVISION	DATE/BY	APPROVE

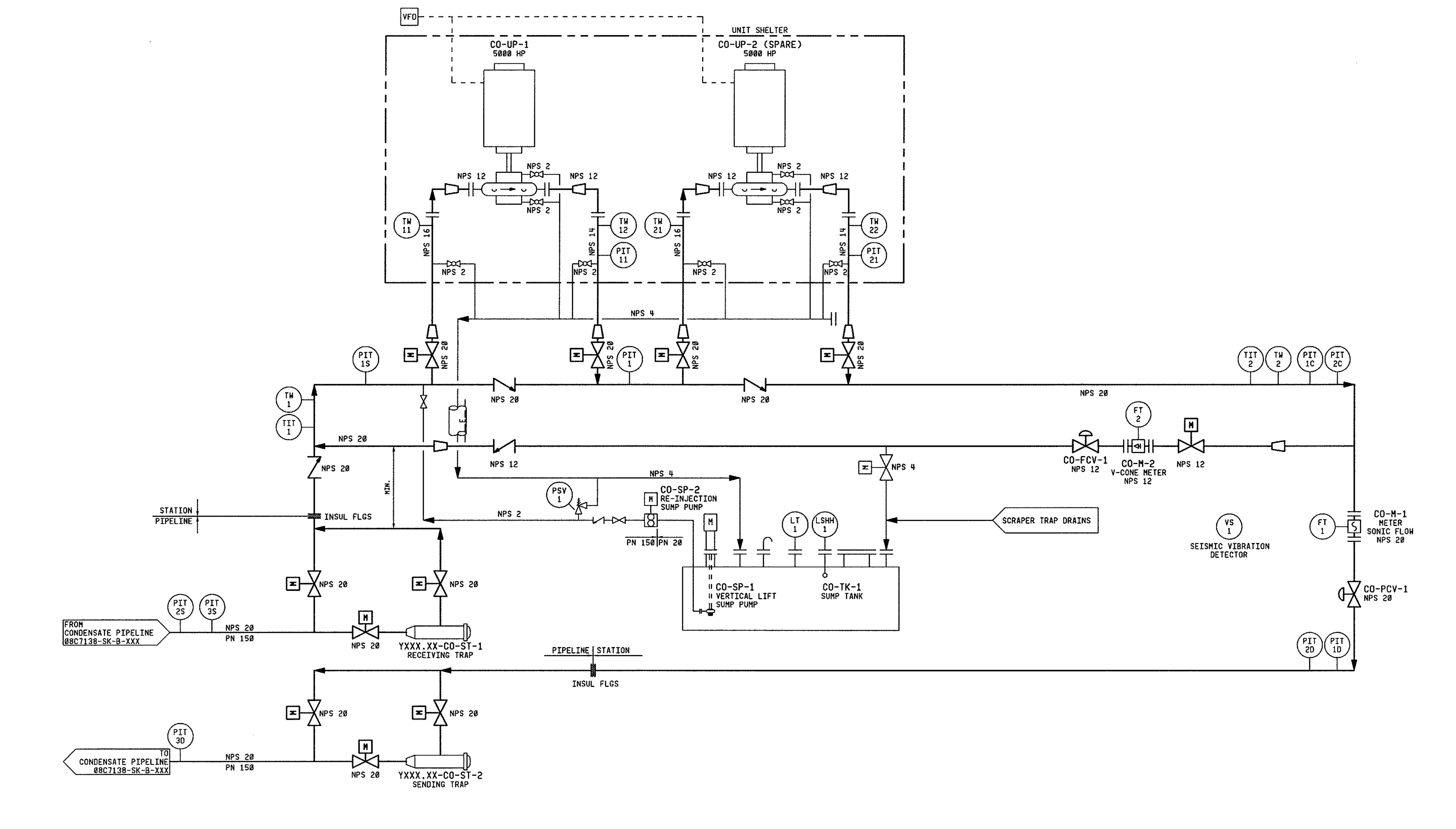
ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
BURNS LAKE STATION
OIL PUMPS
PROCESS FLOW DIAGRAM

DRAWN	RM	CHECK		APPROVE	
DATE	07 NOV 06	SCALE	NTS	APPROVE	

08C7138-SK-B-116

H-23



NOTES:

1. ALL PIPING PN 150 UNLESS NOTED OTHERWISE.
2. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "CO-".
3. FUNCTIONAL SYSTEM CODE CO- INDICATES CONDENSATE MAINLINE.
4. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "YXXX.XX".
5. EACH PUMP AND PUMP MOTOR UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
6. EACH PUMP UNIT SHELTER INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, AND AMBIENT TEMPERATURE MONITOR.
7. BUILDINGS AND CONFINED SPACES ARE EQUIPPED WITH A HEAT DETECTOR, SMOKE DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
8. STATION LOCATION AND NUMBER OF PUMPS ARE BASED ON ENBRIDGE HYDRAULICS SUPPLIED JUNE 2008.
9. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
10. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

1. STATION KP AND ASSOCIATED LOCATION CODE.

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

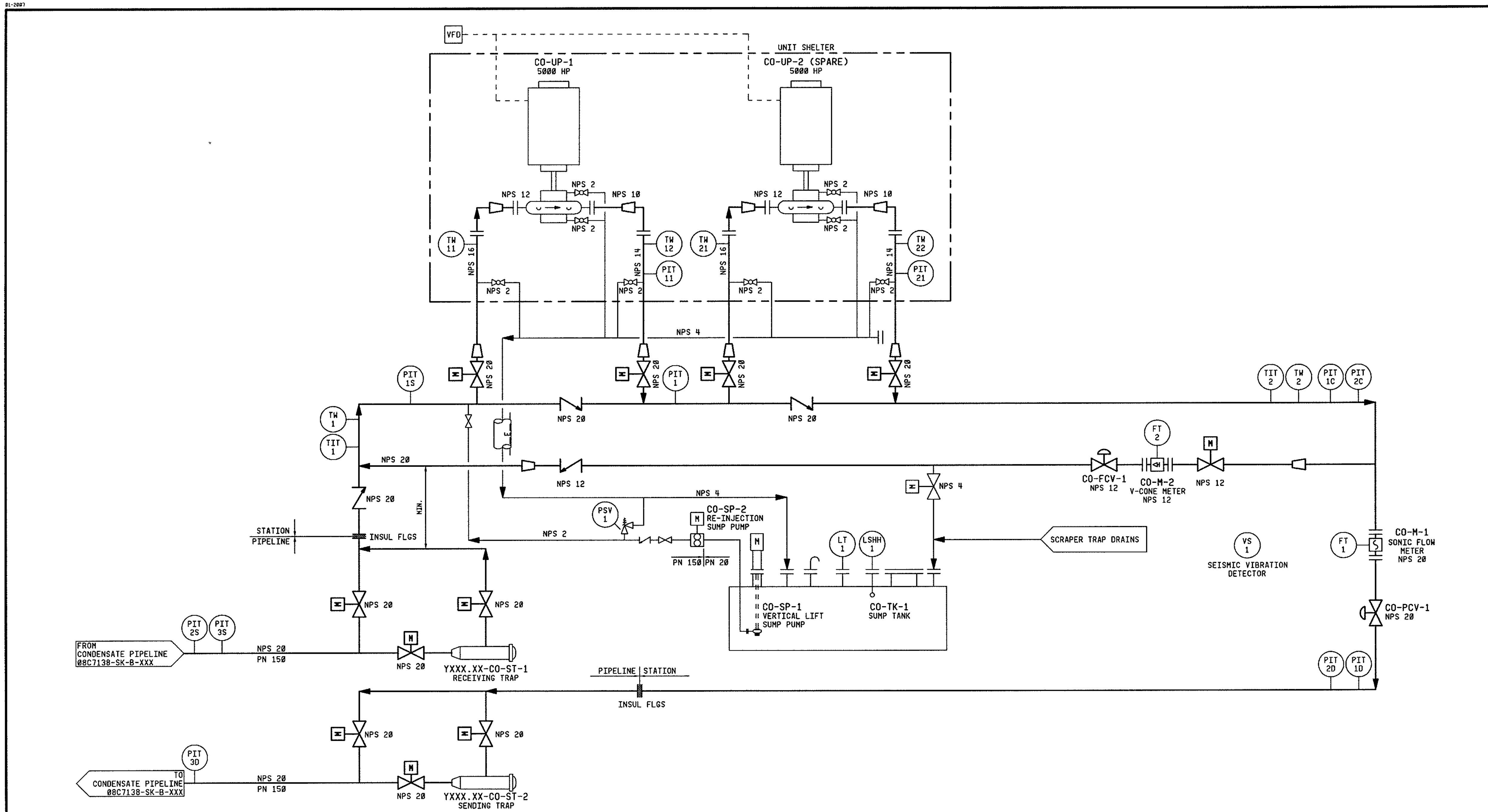
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
BURNS LAKE STATION
CONDENSATE PUMPS
PROCESS FLOW DIAGRAM

DRAWN	RM	CHECK		APPROVE	
DATE	07 NOV 06	SCALE	NTS	APPROVE	

08C7138-SK-B-176 | H-24



NOTES:

1. ALL PIPING PN 150 UNLESS NOTED OTHERWISE.
2. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "CO-".
3. FUNCTIONAL SYSTEM CODE CO- INDICATES CONDENSATE MAINLINE.
4. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "YXXX.XX".
5. EACH PUMP AND PUMP MOTOR UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
6. EACH PUMP UNIT SHELTER INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, AND AMBIENT TEMPERATURE MONITOR.
7. BUILDINGS AND CONFINED SPACES ARE EQUIPPED WITH A HEAT DETECTOR, SMOKE DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
8. STATION LOCATION AND NUMBER OF PUMPS ARE BASED ON ENBRIDGE HYDRAULICS SUPPLIED JUNE 2008.
9. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
10. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

1. STATION KP AND ASSOCIATED LOCATION CODE.

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

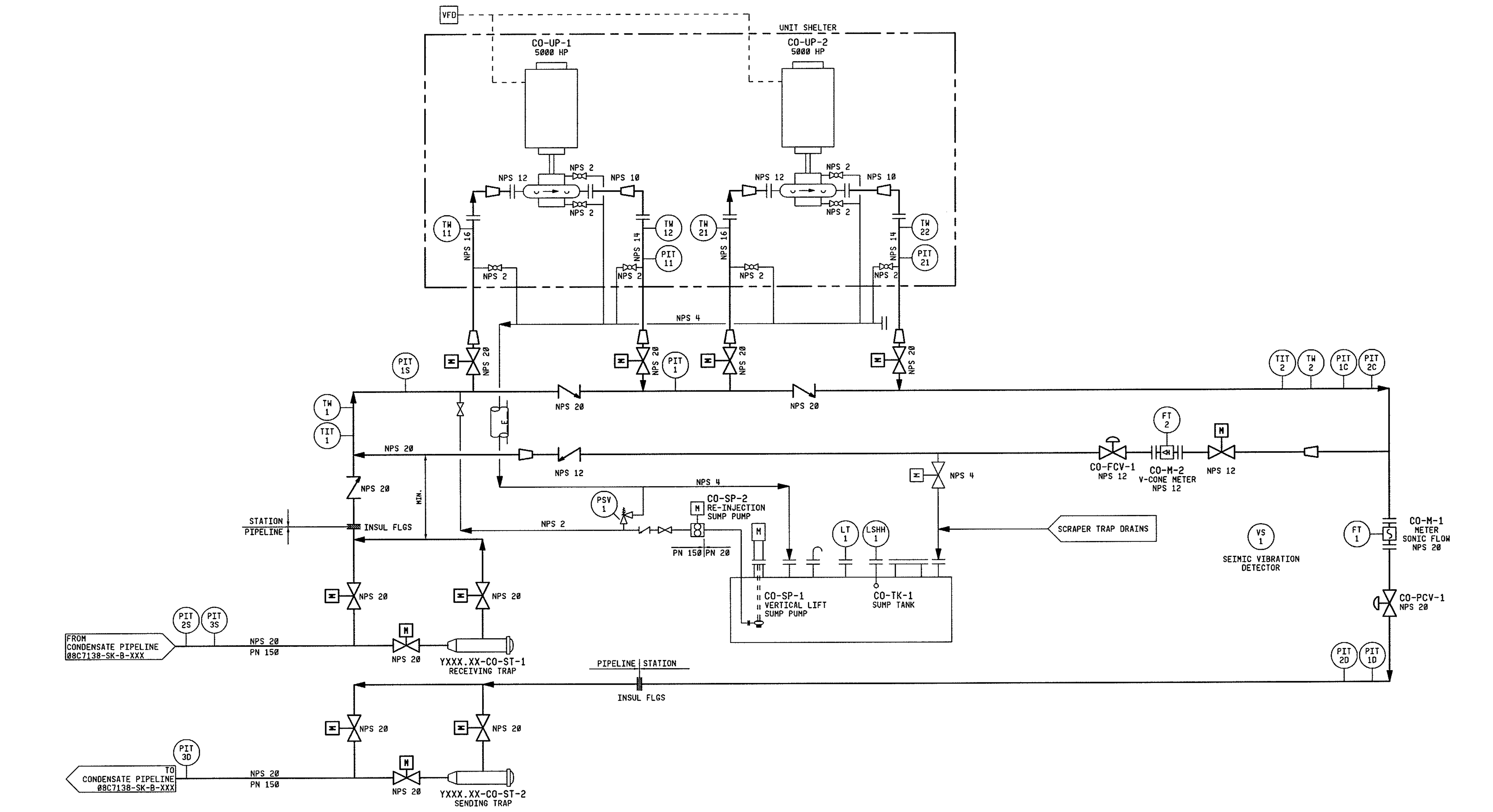
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
HOUSTON STATION
CONDENSATE PUMPS
PROCESS FLOW DIAGRAM

DRAWN	RM	CHECK		APPROVE	
DATE	07 NOV 06	SCALE	NTS	APPROVE	

08C7138-SK-B-156 | H-25



NOTES:

1. ALL PIPING PN 150 UNLESS NOTED OTHERWISE.
2. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "CO-".
3. FUNCTIONAL SYSTEM CODE CO- INDICATES CONDENSATE MAINLINE.
4. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "YXXX.XX".
5. EACH PUMP AND PUMP MOTOR UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
6. EACH PUMP UNIT SHELTER INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, AND AMBIENT TEMPERATURE MONITOR.
7. BUILDINGS AND CONFINED SPACES ARE EQUIPPED WITH A HEAT DETECTOR, SMOKE DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
8. STATION LOCATION AND NUMBER OF PUMPS ARE BASED ON ENBRIDGE HYDRAULICS SUPPLIED JUNE 2008.
9. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
10. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

1. STATION KP AND ASSOCIATED LOCATION CODE.

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
K	ISSUED FOR NEB APPLICATION	14 SEP 09 RTM	

NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

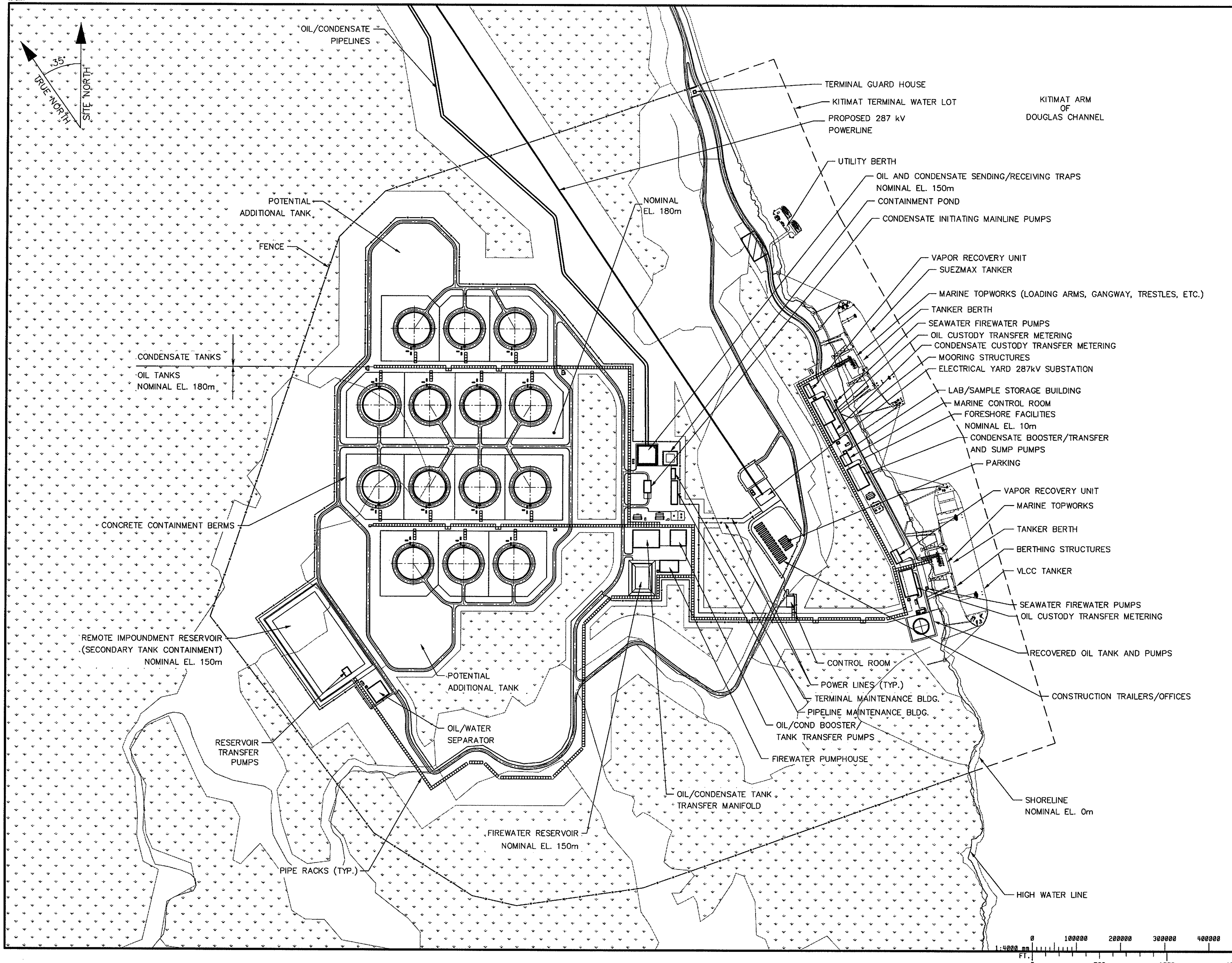
ENBRIDGE NORTHERN GATEWAY PROJECT
CLEARWATER STATION
CONDENSATE PUMPS
PROCESS FLOW DIAGRAM

DRAWN	RM	CHECK		APPROVE	
DATE	07 NOV 06	SCALE	NTS	APPROVE	

08C7138-SK-B-177

H-26

Appendix I Kitimat Terminal Site Drawings



NOTES

1. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.
2. ALL ELEVATIONS SHOWN ON THIS DRAWING ARE GEODETIC.

LEGEND

POST CONSTRUCTION TREE COVERAGE

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	20 OCT 09 RTM	

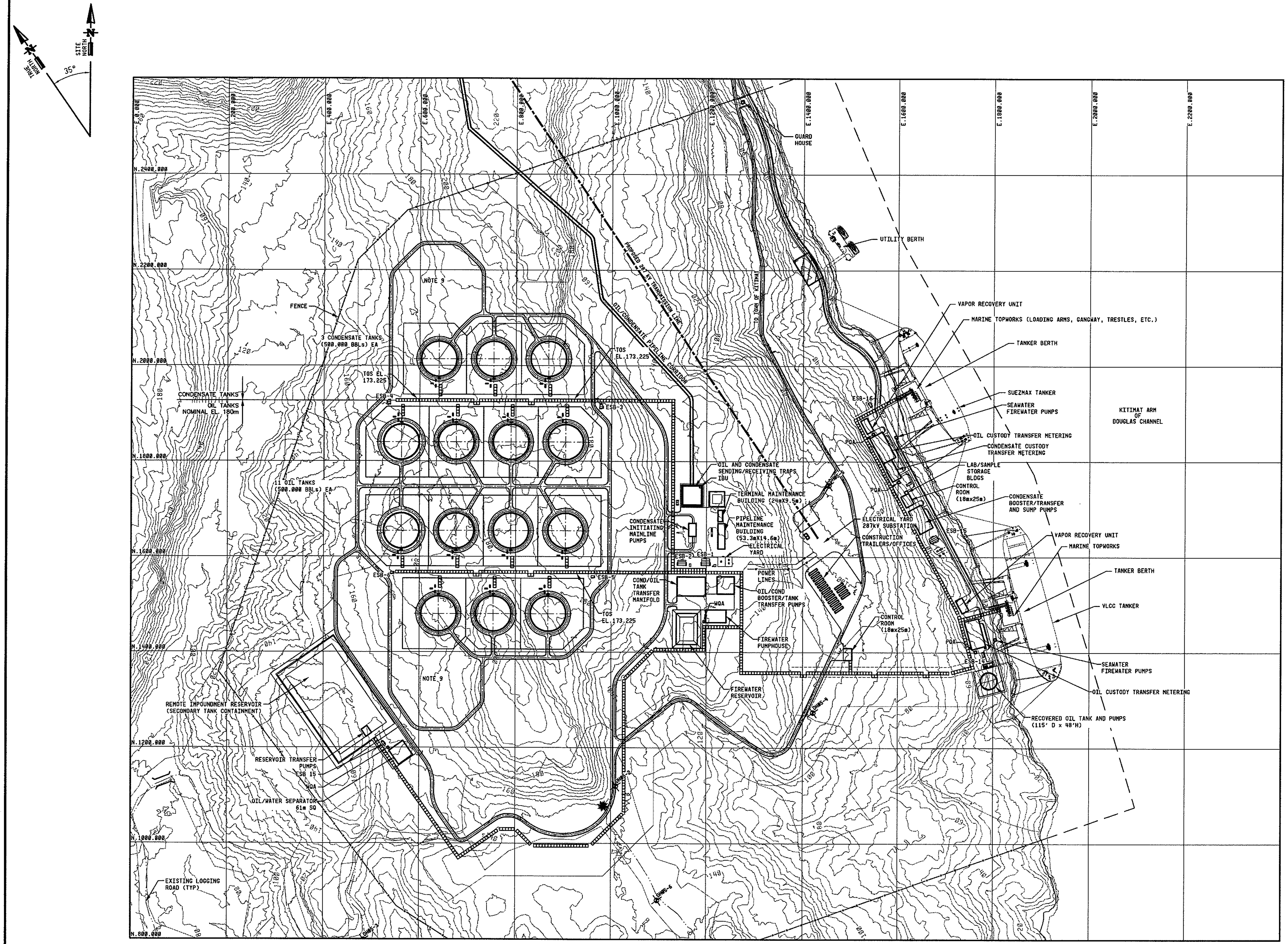
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
PRELIMINARY LAYOUT
PLOT PLAN

DRAWN	RTM	CHECK		APPROVE	
DATE	02 MAR 09	SCALE	1:4000	APPROVE	

08C7138-SK-A-218 I-1



0 100000 200000 300000 400000
1:4000 mm
FT.
0 500 1000 1500

NOTES
1. ALL ELEVATIONS SHOWN ON THIS DRAWING ARE GEODETIC.
2. PLANT DATUM 0,0 IS LOCATED IN UTM ZONE 9 5977m NORTH, 516.5m EAST.
3. MODULE SHIPPING RESTRICTIONS ARE AS FOLLOWS: 12' WIDE x 12' HIGH x 55' LG x 85 000LBS. (CONFIRMATION REQUIRED)
4. UTILITY AIR COMPRESSORS LOCATED IN EACH MAINTENANCE BUILDING.
5. POTABLE WATER LOCATED AT CONTROL ROOMS AND MAINTENANCE SHOPS.
6. AVERAGE TREE HEIGHT AT THIS SITE IS 75'(23m). A DISTANCE OF 100'(30m) WILL BE CLEARED FROM ANY FENCELINE PER ENBRIDGE WILDFIRE THREAT ASSESMENT AND CONTROL GUIDELINES.
7. TANKS ARE 243' IN DIA. AND 60' HIGH. (500,000 bbls NOM)
8. THE LAYDOWN AREA TO BE LOCAL TO WORK, THRU INITIAL STAGES OF CONSTRUCTION, ONCE SPACE IS NOT ADEQUATE, CONSTRUCTION LAYDOWN IS AVAILABE IN THE SOUTH OF THE PROPERTY.
9. POTENTIAL ADDITIONAL TANK.

HOLD
TEMPORARY CONSTRUCTION LAYDOWN AREA FOR:
1. INTERIM OVERBURDEN AND ROCK PROCESSING AREA.

HOLD
PERMANENT LOCATION FOR THE FOLLOWING NEED TO BE DETERMINED AND OR REMOVED FROM SCOPE:
1. HAZARDOUS WASTE SHED
2. ANODE BED LOCATIONS
3. RECLAMATION STOCKPILE AREA.

LEGEND

	EXISTING LOGGING ROAD
	POTENTIAL CULTURALLY MODIFIED TREE(CMT)
IBU	INSTRUMENTATION BUILDING
WQA	WATER QUALITY BUILDING
PQA	PRODUCT QUALITY BUILDING
	PROPOSED 287 kV TRANSMISSION LINE R of W (48m WIDE)

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	20 OCT 09 RTM	

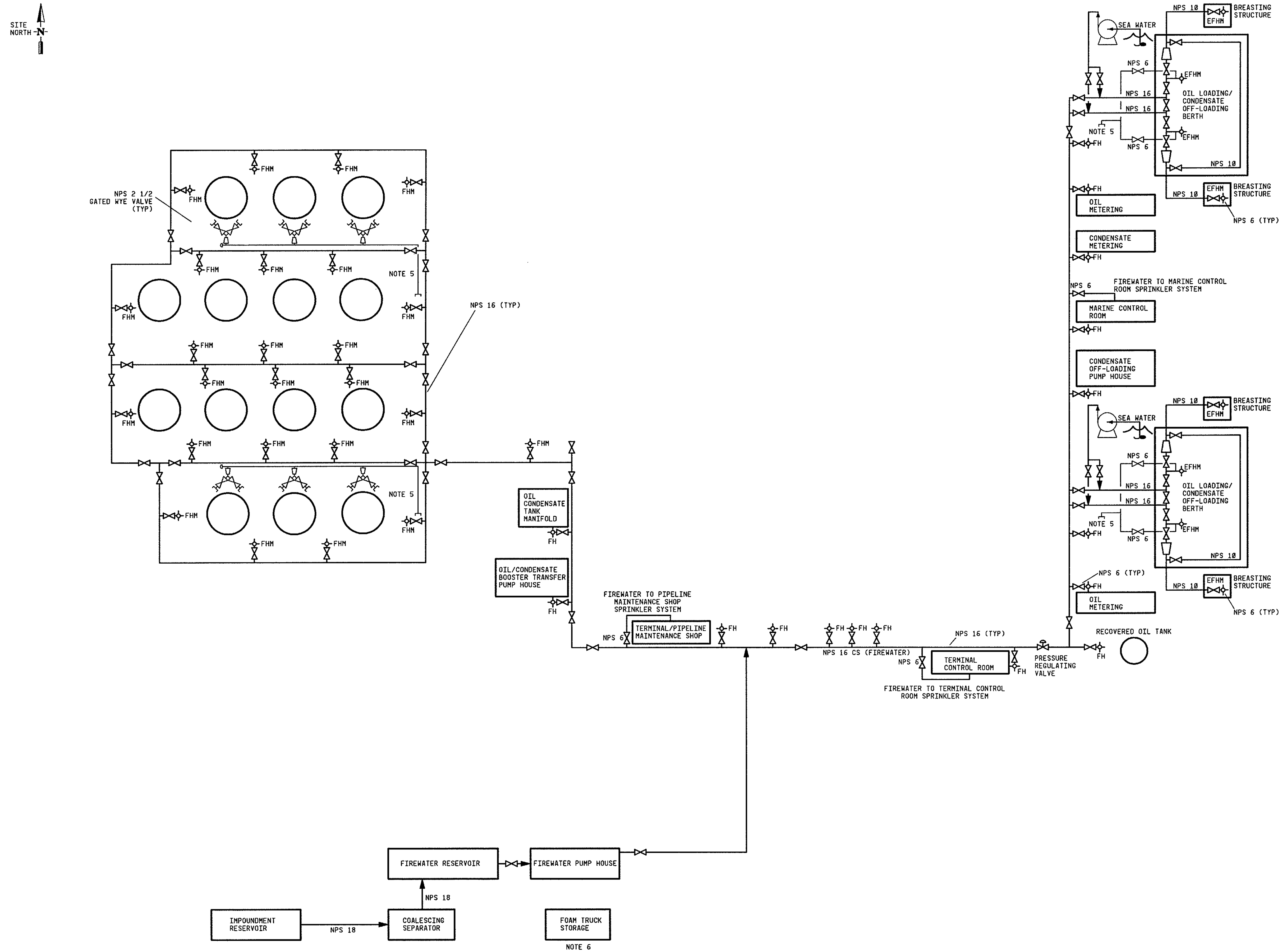
NO	REVISION	DATE/BY	APPROVE

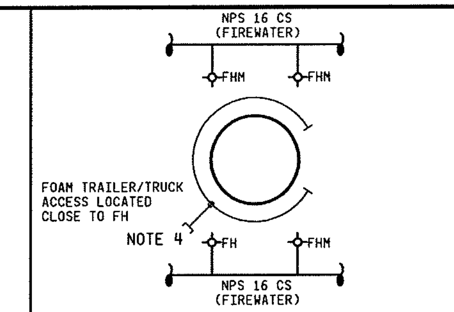
ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
PRELIMINARY LAYOUT WITH CONTOURS
PLOT PLAN

DRAWN JF/RTM	CHECK	APPROVE	
DATE 04 SEP 08	SCALE 1:4000	APPROVE	

08C7138-SK-A-213E I-2





TYPICAL TANK FIRE PROTECTION DETAIL

NOTES:

1. ALL HYDRANTS & MONITORS TO BE LOCATED OUTSIDE BERM.
2. HYDRANTS LOCATED BASED ON 240' SPRAY PATTERN.
3. HEAT TRACE AND INSULATE ALL FIREWATER PIPING.
4. EACH TANK HAS A TANK FOAM RING WITH A CONNECTION LOCATED WITHIN 10' OF A FIRE HYDRANT AND A MINIMUM OF 3 FIRE MONITORS.
5. NOTED PIPE IS NPS 6 GALVANIZED FOAM INJECTION HEADER.
6. FOAM TRUCK STORAGE TO BE ON INDEPENDENT SYSTEM.
7. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

LEGEND:

FH ——— FIRE HYDRANT
FHM ——— FIRE HYDRANT MONITOR
EFHM ——— ELEVATED FIRE HYDRANT MONITOR (REMOTE CONTROLLED)

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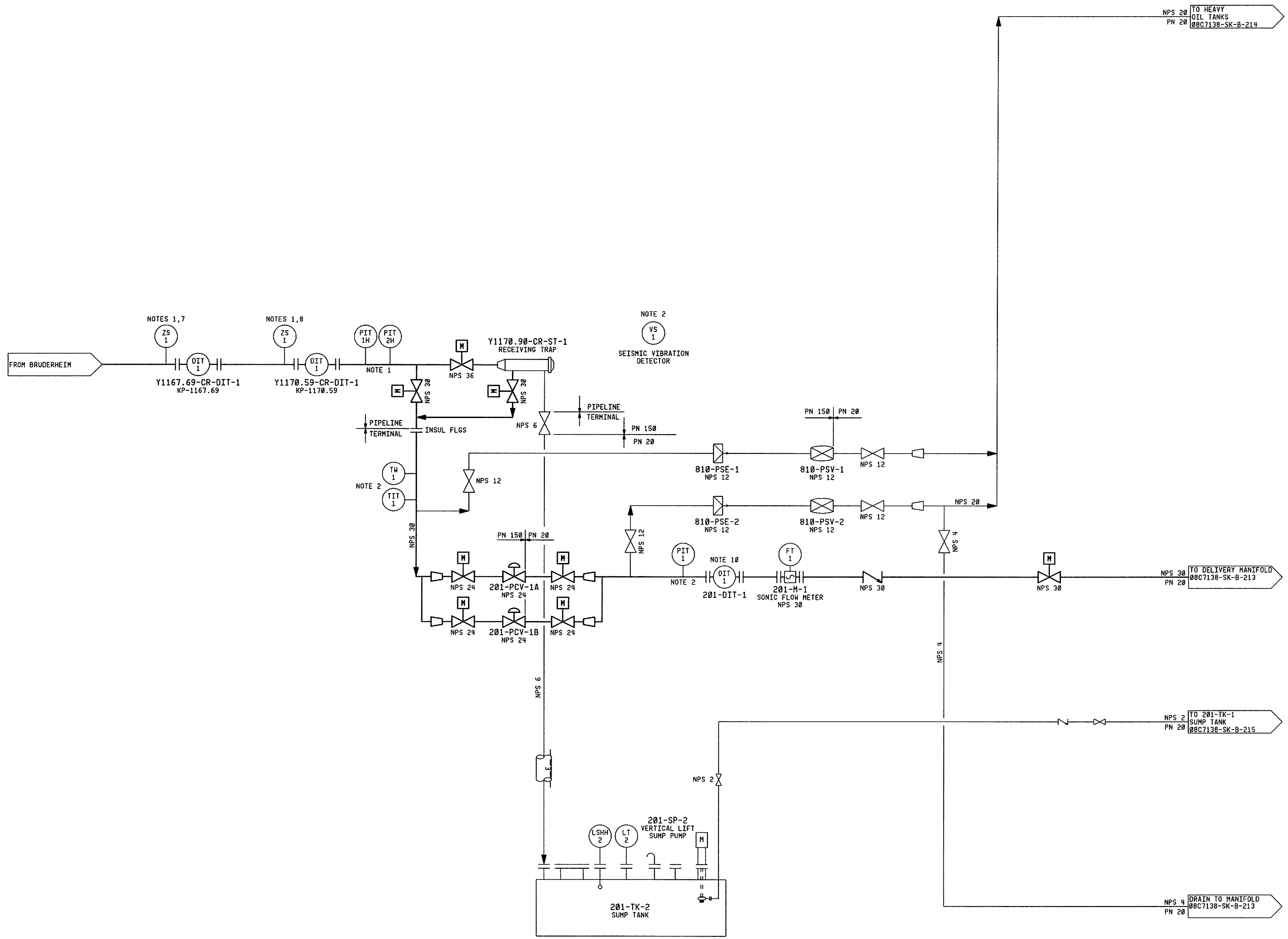
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
PROPOSED FIREWATER AND FOAM SYSTEM
FLOW SCHEMATIC

DRAWN ALS	CHECK	APPROVE
DATE 10 OCT 06	SCALE NTS	APPROVE

08C7138-SK-B-203 | I-3



NOTES:

1. PREFIX FOR ALL CONTROL / MEASUREMENT INSTRUMENTS IS "CR-".
2. PREFIX FOR ALL CONTROL / MEASUREMENT INSTRUMENTS IS "201-".
3. PREFIX FOR ALL CONTROL / MEASUREMENT INSTRUMENTS IS "810-".
4. FUNCTIONAL SYSTEM CODE "CR-" INDICATES OIL MAINLINE.
5. FUNCTIONAL SYSTEM CODE "201-" INDICATES OIL COMMODITY TRANSFER.
6. FUNCTIONAL SYSTEM CODE "810-" INDICATES EMERGENCY OIL RELIEF.
7. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "Y1167.69".
8. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "Y1170.59".
9. LOCATION CODE FOR ALL REMAINING INSTRUMENTS, EQUIPMENT, ETC. IS "KT" FOR KITIMAT TANKAGE.
10. DENSITOMETER FOR LEAK DETECTION PURPOSES.
11. BUILDINGS AND CONFINED SPACES ARE EQUIPPED WITH A HEAT DETECTOR, SMOKE DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
12. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
13. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

1. LOCATION CODE FOR REMOTE INSTRUMENTS, EQUIPMENT, RECEIVING TRAP, ETC.

Colt Engineering Corporation

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(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
1	ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

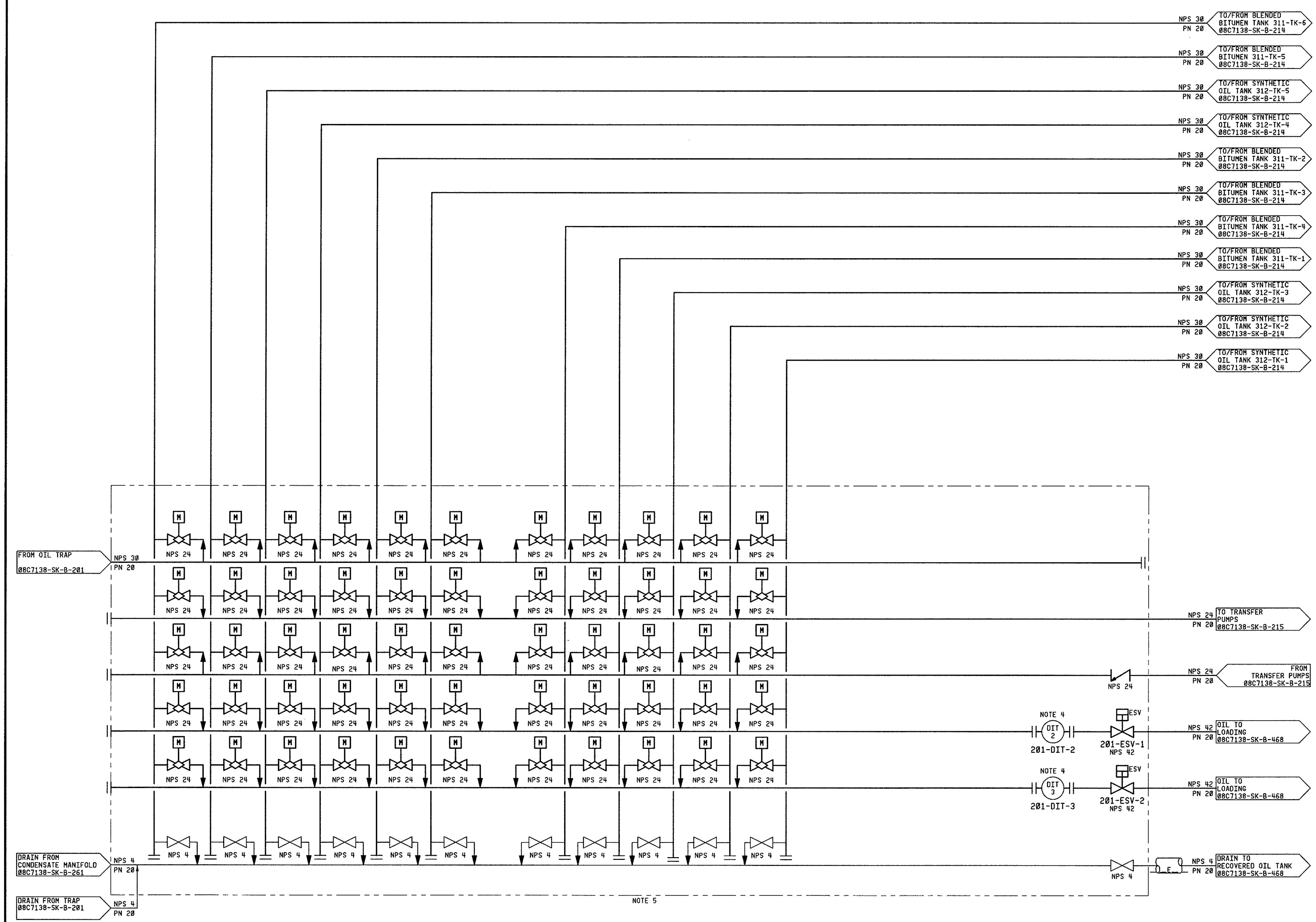
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
OIL RECEIVING TRAP
PROCESS FLOW DIAGRAM

DRAWN ALS	CHECK	APPROVE
DATE 10 OCT 06	SCALE	APPROVE

08C7138-SK-B-201 | I-4



NOTES:

1. FUNCTIONAL SYSTEM CODE "201-" INDICATES OIL COMMODITY TRANSFER.
2. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "KT" FOR KITIMAT TANKAGE.
3. BUILDINGS AND CONFINED SPACES ARE EQUIPPED WITH A HEAT DETECTOR, SMOKE DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR. ON DRAWING CONTINUATIONS OR OTHER REFERENCES.
4. DENSITOMETER IS FOR BATCH DETECTION PURPOSES.
5. BUILDING IS SHARED WITH CONDENSATE MANIFOLD.
6. ALL PIPING IS PN20 UNLESS OTHERWISE NOTED.
7. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
8. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
K	ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

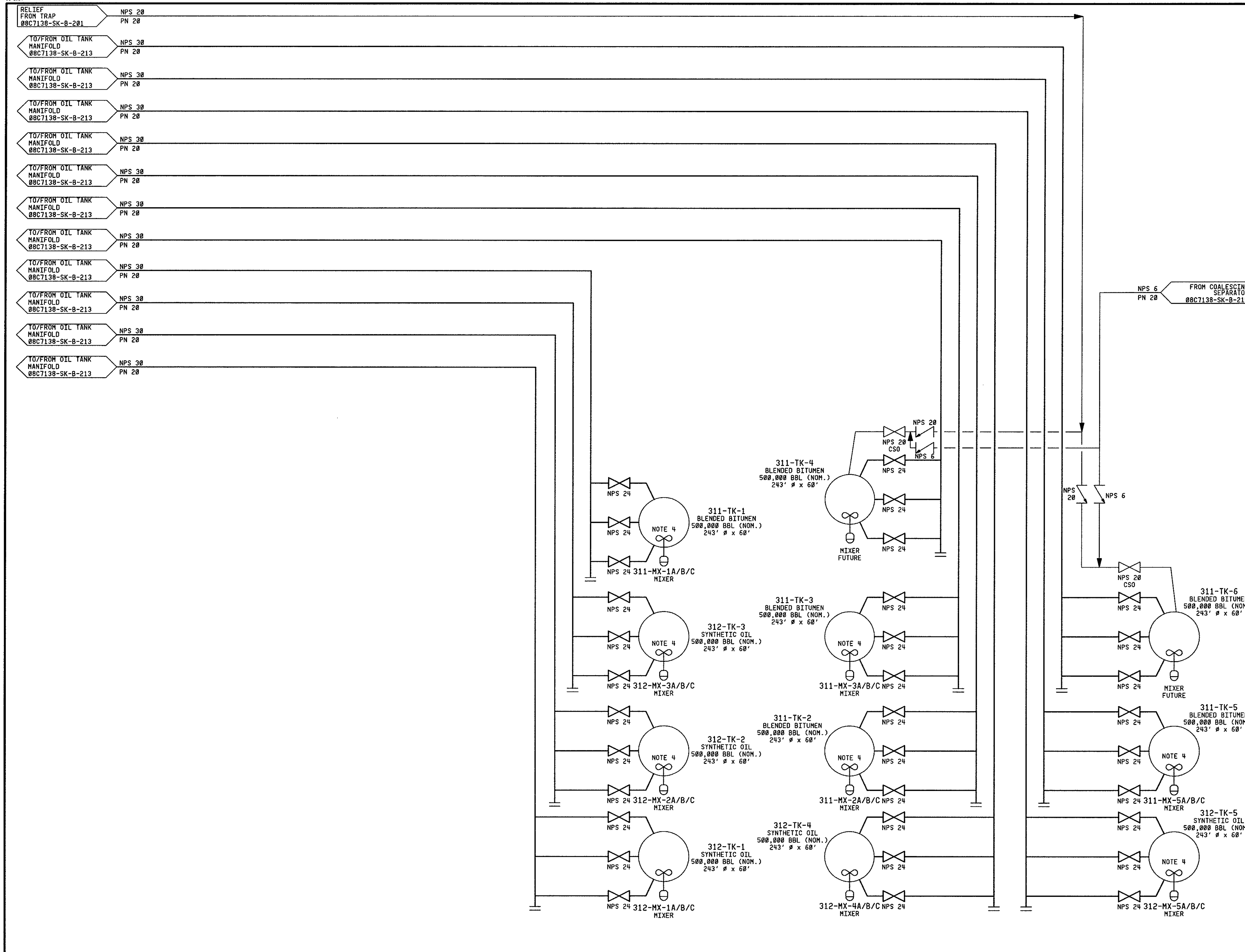
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
OIL TANK MANIFOLD
PROCESS FLOW DIAGRAM

DRAWN ALS	CHECK	APPROVE
DATE 06 OCT 06	SCALE NTS	APPROVE

08C7138-SK-B-213 I-5



NOTES:

1. FUNCTIONAL SYSTEM CODE "311-" INDICATES BLENDED BITUMEN COMMODITY TANKAGE.
2. FUNCTIONAL SYSTEM CODE "312-" INDICATES SYNTHETIC OIL COMMODITY TANKAGE.
3. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "KT-" FOR KITIMAT TANKAGE.
4. NOTED TANKS ARE CAPABLE OF HOLDING AND DELIVERING SYNTHETIC OIL OR BLENDED BITUMEN. PRIMARY PRODUCT IS INDICATED ON THE EQUIPMENT TAG.
5. EACH TANK INCLUDES A UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
6. EACH 500,000 BBL TANK IS EQUIPPED WITH LINEAR ROOF SEAL FIRE DETECTION.
7. TANK FARM INCLUDES CAMERA SYSTEM FOR SECURITY AND SAFETY PURPOSES.
8. BUILDINGS AND CONFINED SPACES ARE EQUIPPED WITH A HEAT DETECTOR, SMOKE DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
9. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
10. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

Colt Engineering Corporation

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(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
1	ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

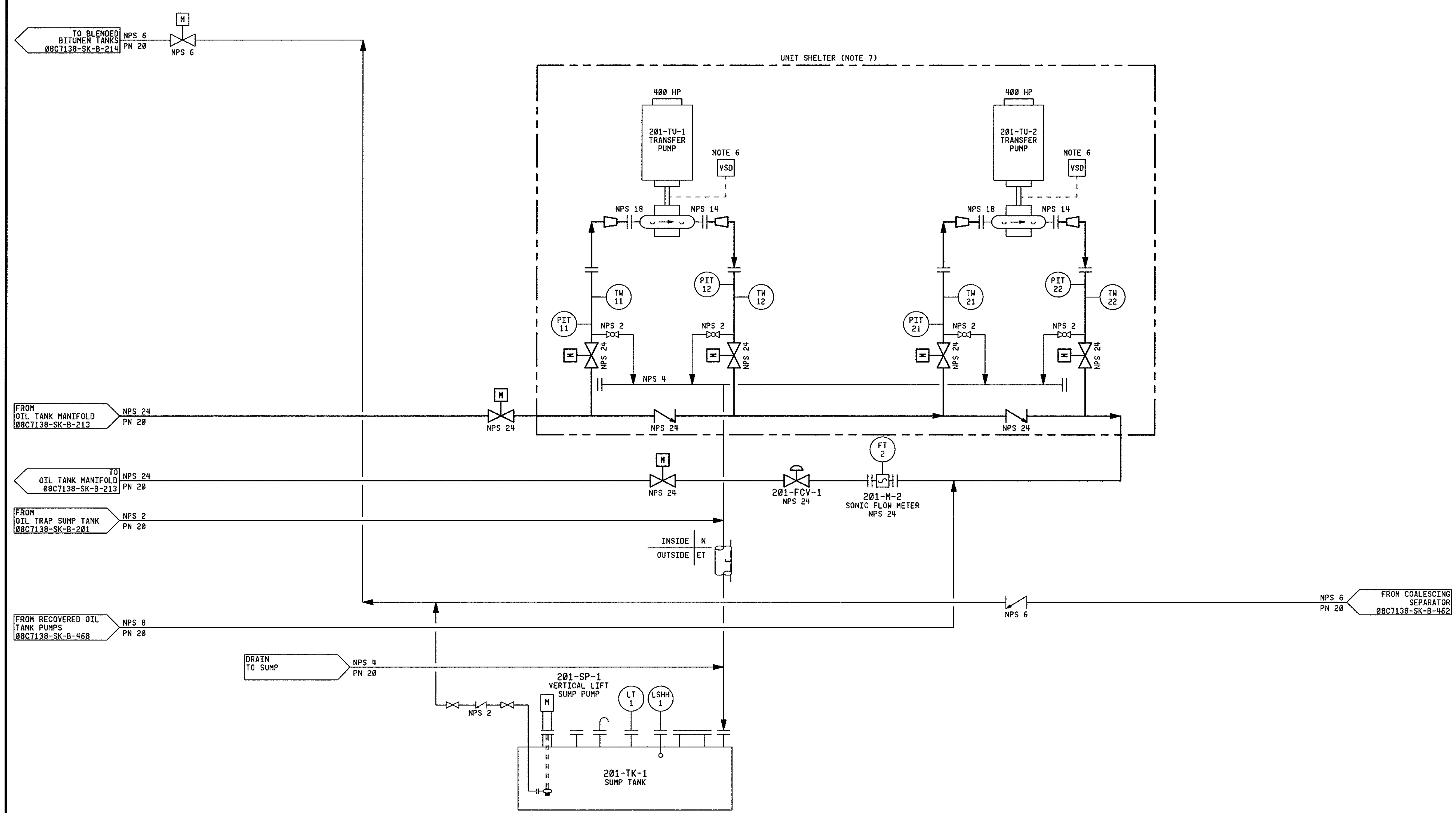
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
OIL TANK AREA
PROCESS FLOW DIAGRAM

DRAWN	ALS	CHECK		APPROVE	
DATE	05 OCT 06	SCALE		APPROVE	

08C7138-SK-B-214 | I-6



NOTES:

1. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "201-".
2. FUNCTIONAL SYSTEM CODE "201-" INDICATES OIL COMMODITY TRANSFER.
3. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "KT" FOR KITIMAT TANKAGE.
4. EACH PUMP AND PUMP MOTOR UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
5. EACH PUMP UNIT SHELTER INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, AND AMBIENT TEMPERATURE MONITOR.
6. PUMP SPEED CONTROLLED BY A MAGNETIC ADJUSTABLE SPEED COUPLING DRIVE.
7. THE BUILDING IS SHARED WITH CONDENSATE TRANSFER PUMPS.
8. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
9. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
1	ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

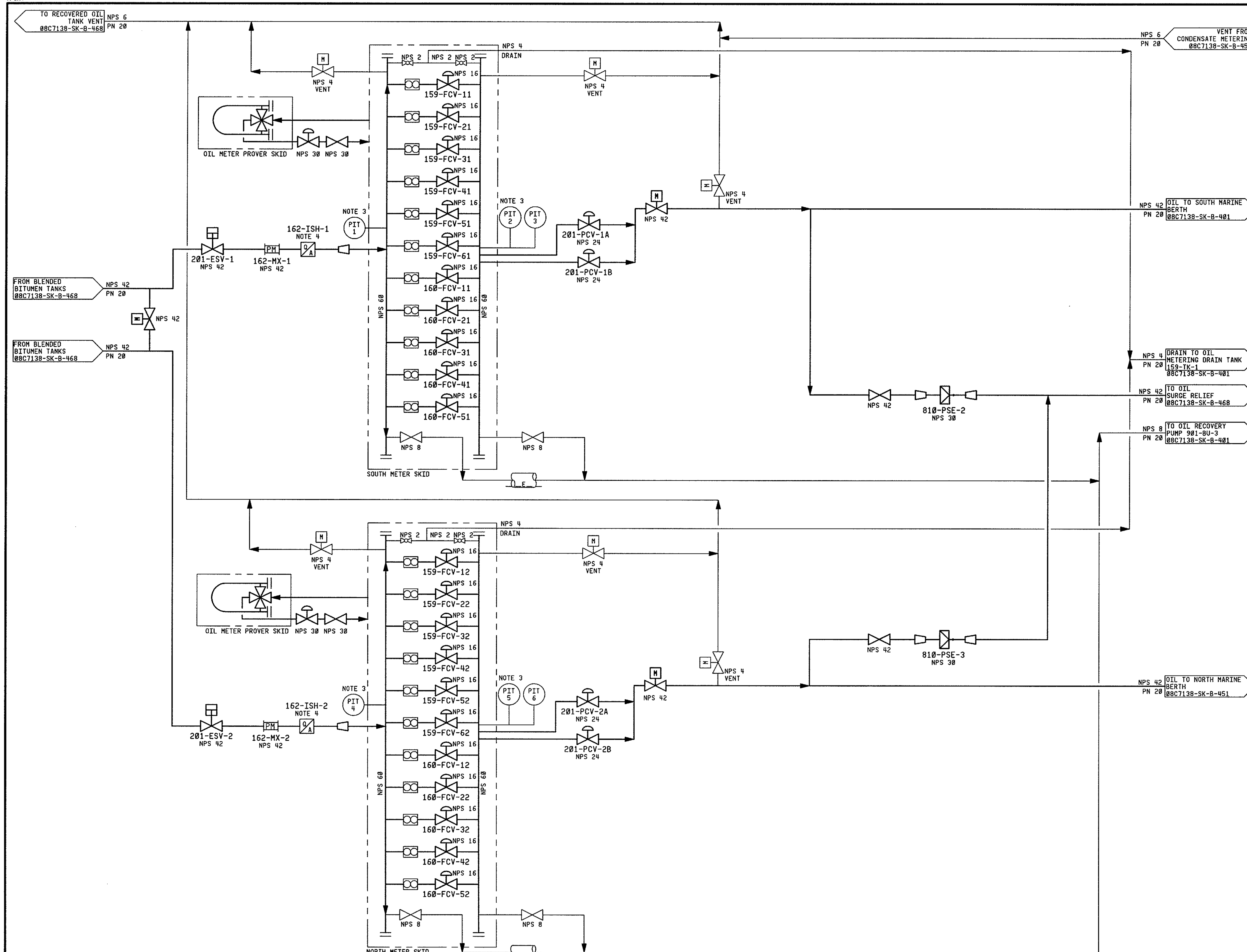
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
OIL TRANSFER PUMPS
PROCESS FLOW DIAGRAM

DRAWN	ALS	CHECK		APPROVE	
DATE	11 OCT 06	SCALE		APPROVE	

08C7138-SK-B-215 I-7



NOTES:

1. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "KM" FOR KITIMAT MARINE.
2. ALL PIPING IS PN 20 UNLESS OTHERWISE NOTED.
3. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "159-".
4. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "162-".
5. FUNCTIONAL SYSTEM CODE "159-" AND "160-" INDICATES GENERAL OUTGOING OIL CUSTODY TRANSFER.
6. FUNCTIONAL SYSTEM CODE "162-" INDICATES OUTGOING OIL CUSTODY TRANSFER METERING.
7. FUNCTIONAL SYSTEM CODE "810-" INDICATES EMERGENCY OIL RELIEF.
8. FUNCTIONAL SYSTEM CODE "201-" INDICATES OIL COMMODITY TRANSFER.
9. ANALYTICAL INSTRUMENTS FOR OIL Q/A INCLUDE A DENSITOMETER AND BASIC SEDIMENT AND WATER ANALYZER.
10. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
11. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

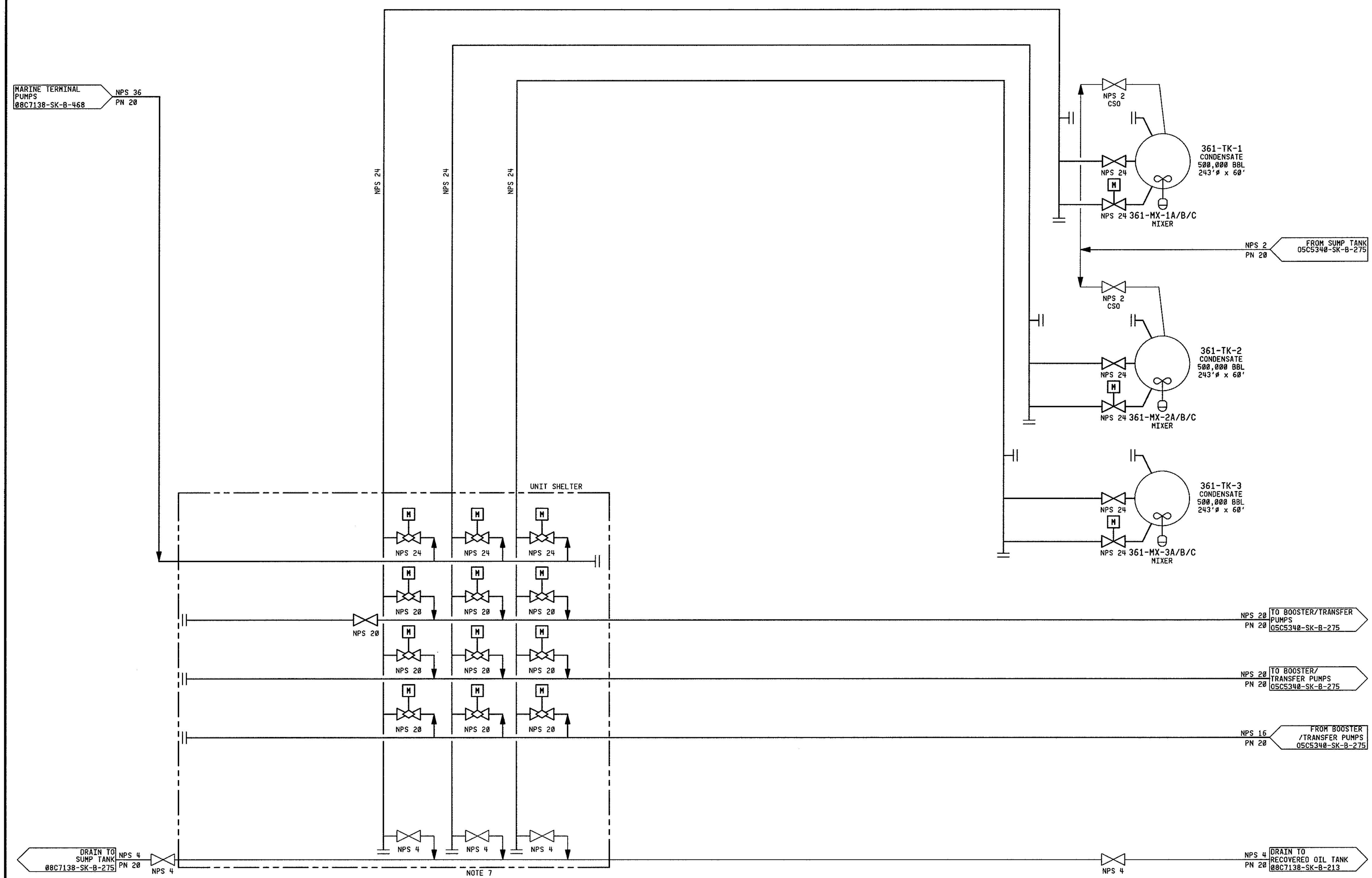
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
OIL METERING
PROCESS FLOW DIAGRAM

DRAWN	RTM	CHECK		APPROVE	
DATE	17 NOV 08	SCALE		APPROVE	

08C7138-SK-B-400 I-8



NOTES:

1. FUNCITONAL SYSTEM CODE "361-" INDICATES CONDENSATE COMMODITY TANKAGE.
2. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "KT" FOR KITIMAT TANKAGE.
3. EACH TANK INCLUDES A UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
4. EACH 500,000 BBL TANK IS EQUIPPED WITH LINEAR ROOF SEAL FIRE DETECTION.
5. TANK FARM INCLUDES CAMERA SYSTEM FOR SECURITY AND SAFETY PURPOSES.
6. BUILDINGS AND CONFINED SPACES ARE EQUIPPED WITH A HEAT DETECTOR, SMOKE DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
7. BUILDING IS SHARED WITH OIL MANIFOLD.
8. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
9. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

Colt Engineering Corporation

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(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
J	ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

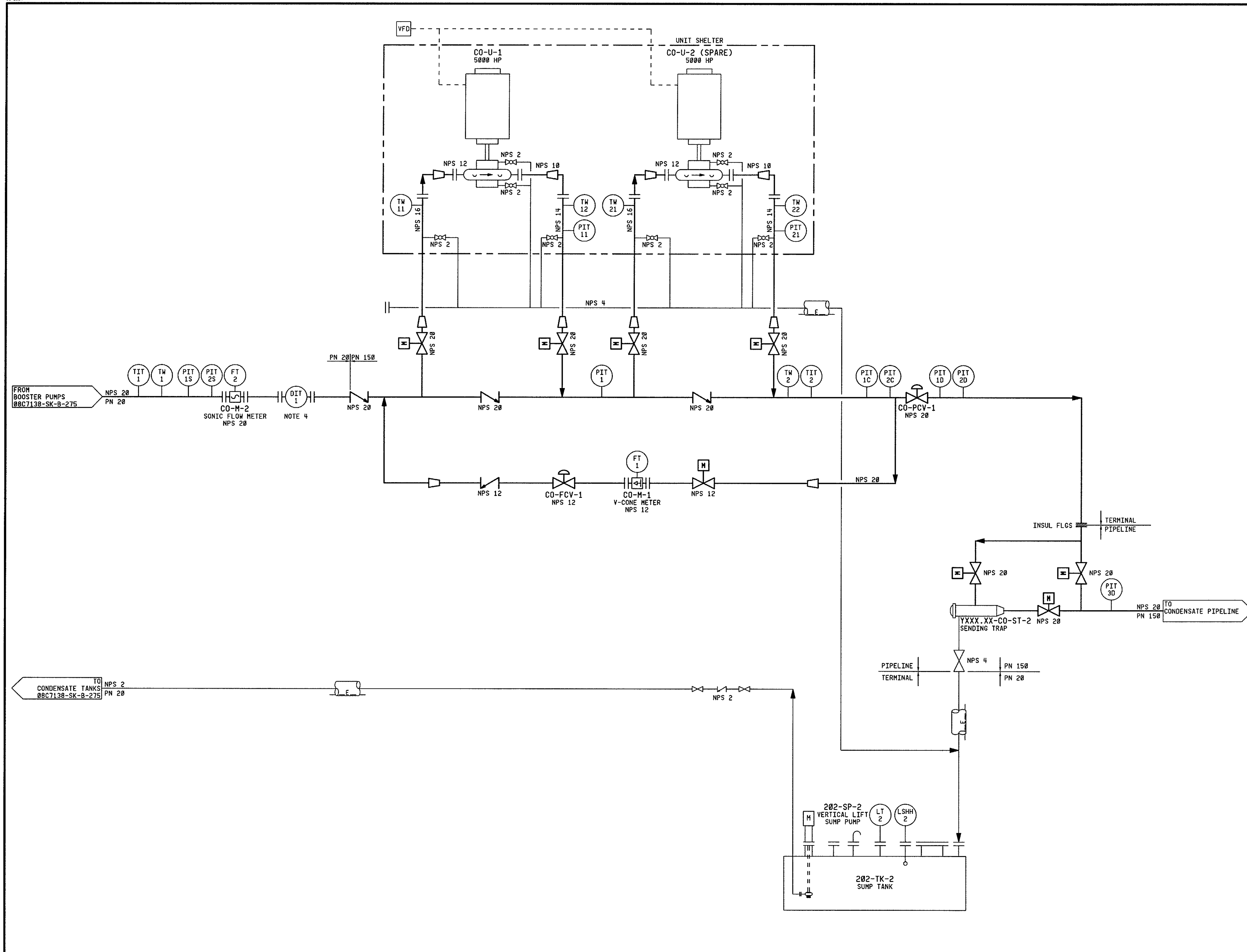
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
CONDENSATE MANIFOLD AND TANK AREA
PROCESS FLOW DIAGRAM

DRAWN SEM	CHECK	APPROVE
DATE 17 MAY 06	SCALE	APPROVE

08C7138-SK-B-261 | I-9



NOTES:

1. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "CO-".
2. FUNCTIONAL SYSTEM CODE "CO-" INDICATES CONDENSATE MAINLINE
3. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "KT" FOR KITIMAT TANKAGE.
4. DENSITOMETER FOR LEAK DETECTION PURPOSES.
5. EACH PUMP AND PUMP MOTOR UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
6. EACH PUMP UNIT SHELTER INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, AND AMBIENT TEMPERATURE MONITOR.
7. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
8. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	04 SEP 09 RTM	

NO	REVISION	DATE/BY	APPROVE

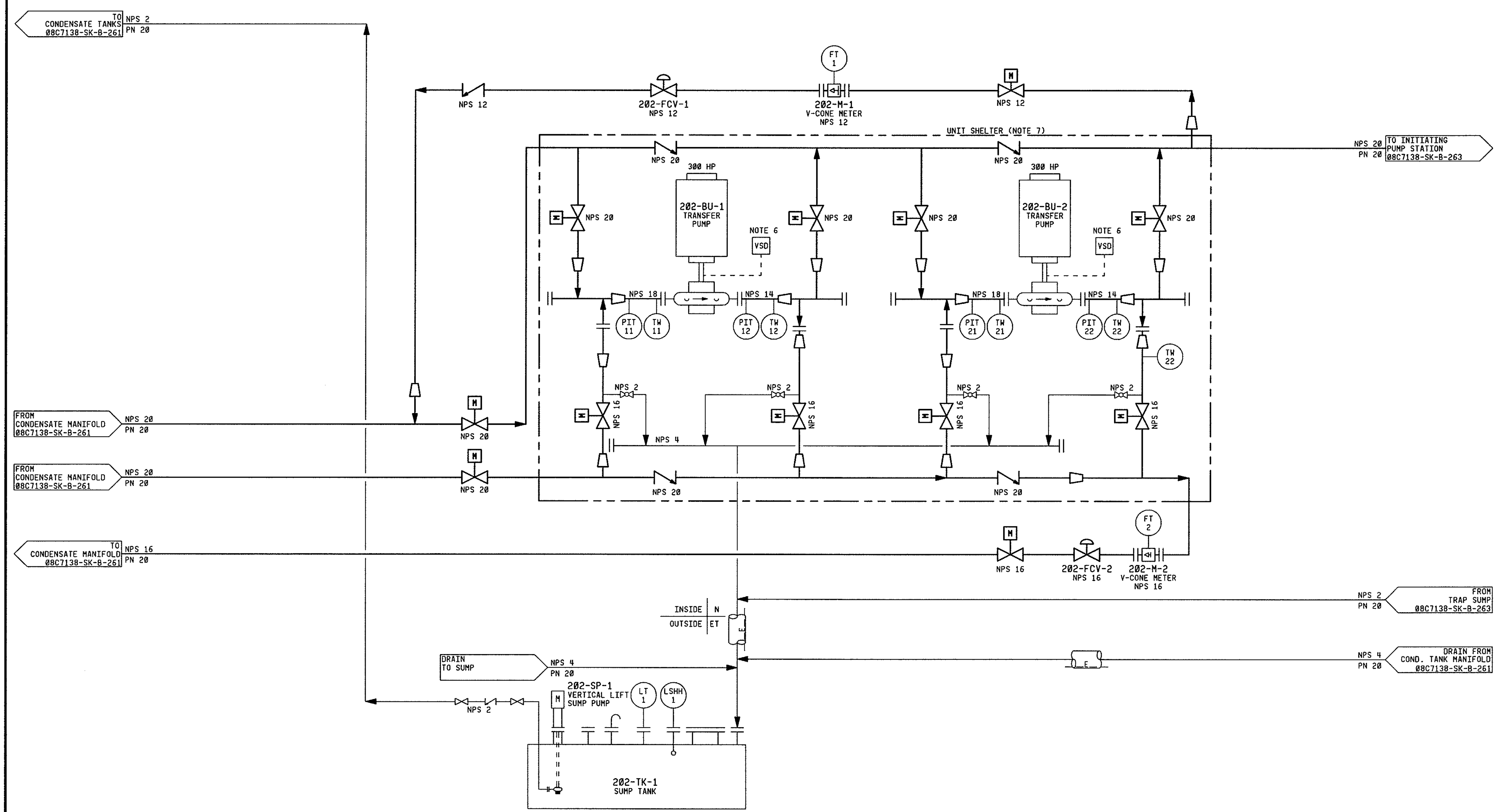
ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
CONDENSATE INITIATING PUMPS
PROCESS FLOW DIAGRAM

DRAWN	ALS	CHECK		APPROVE	
DATE	11 OCT 06	SCALE		APPROVE	

08C7138-SK-B-263 I-10

01-2007



NOTES:

1. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "202-".
2. FUNCTIONAL SYSTEM CODE "202-" INDICATES CONDENSATE COMMODITY TRANSFER.
3. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "KT" FOR KITIMAT TANKAGE.
4. EACH PUMP AND PUMP MOTOR UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
5. EACH PUMP UNIT SHELTER INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, AND AMBIENT TEMPERATURE MONITOR.
6. PUMP SPEED CONTROLLED BY A MAGNETIC ADJUSTABLE SPEED COUPLING DRIVE.
7. PUMP SHELTER SHARED WITH OIL TRANSFER PUMPS.
8. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
9. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
1	ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

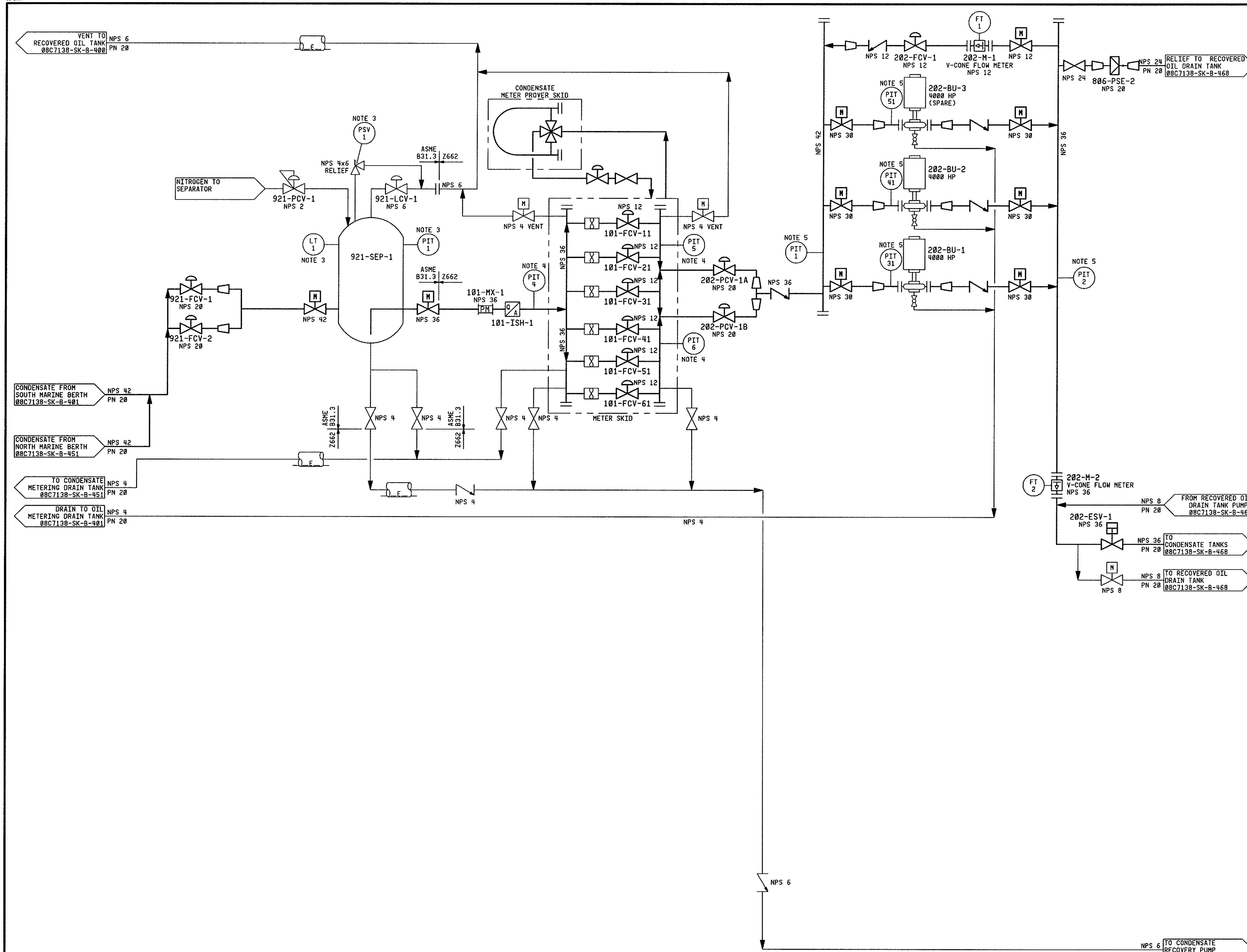
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
CONDENSATE BOOSTER/TRANSFER PUMPS
PROCESS FLOW DIAGRAM

DRAWN ALS	CHECK	APPROVE
DATE 11 OCT 06	SCALE	APPROVE

08C7138-SK-B-275 | I-11



NOTES:

1. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "KM" FOR KITIMAT MARINE.
2. ALL PIPING IS PN 20 UNLESS OTHERWISE NOTED.
3. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "921-".
4. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "101-".
5. PREFIX FOR ALL REMAINING CONTROL/MEASUREMENT INSTRUMENTS IS "202-".
6. FUNCTIONAL SYSTEM CODE "921-" INDICATES VAPOUR RECOVERY.
7. FUNCTIONAL SYSTEM CODE "101-" INDICATES CONDENSATE CUSTODY TRANSFER METERING.
8. FUNCTIONAL SYSTEM CODE "202-" INDICATES CONDENSATE COMMODITY TRANSFER.
9. EACH PUMP AND PUMP MOTOR UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
10. ANALYTICAL INSTRUMENTS FOR CONDENSATE Q/A INCLUDE A DENSITOMETER AND BASIC SEDIMENT AND WATER ANALYZER.
11. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
12. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY (GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

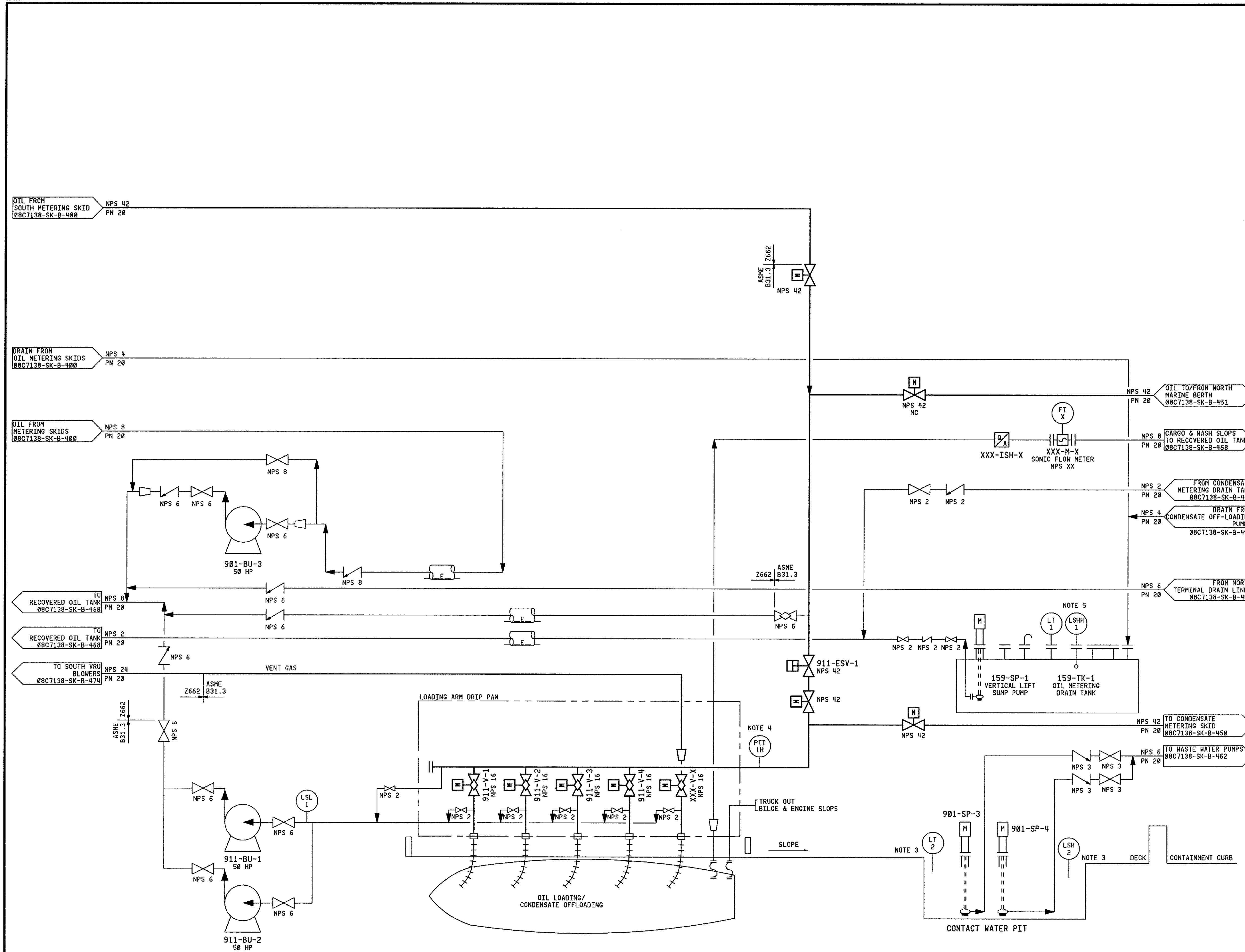
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
CONDENSATE METERING
PROCESS FLOW DIAGRAM

DRAWN	RTM	CHECK		APPROVE
DATE	17 NOV 08	SCALE	NTS	APPROVE

08C7138-SK-B-450 I-12



NOTES:

1. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "KM" FOR KITIMAT MARINE.
2. ALL PIPING IS PN 20 UNLESS OTHERWISE NOTED.
3. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "901-".
4. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "911-".
5. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "159-".
6. FUNCTIONAL SYSTEM CODE "901-" INDICATES WATER SEPARATION OR PRODUCT RECOVERY.
7. FUNCTIONAL SYSTEM CODE "911-" INDICATES OIL RECEIPT.
8. FUNCTIONAL SYSTEM CODE "159-" INDICATES GENERAL OUTGOING OIL CUSTODY TRANSFER.
9. EACH PUMP AND PUMP MOTOR UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
10. BUILDINGS AND CONFINED SPACES ARE EQUIPPED WITH A HEAT DETECTOR, SMOKE DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
11. SIX DISTINCT SYSTEMS EXIST ON SHIP UNLOADING BERTH: DOCKING AID SYSTEM, CENTRAL INTEGRATED MONITORING, ELECTRIC REMOTE RELEASE, MOORING UNLOADING MONITORING, ENVIRONMENTAL MONITORING, AND A CAMERA SYSTEM.
12. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
13. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
1	ISSUED FOR NEB APPLICATION	04 SEP 09 RTM	

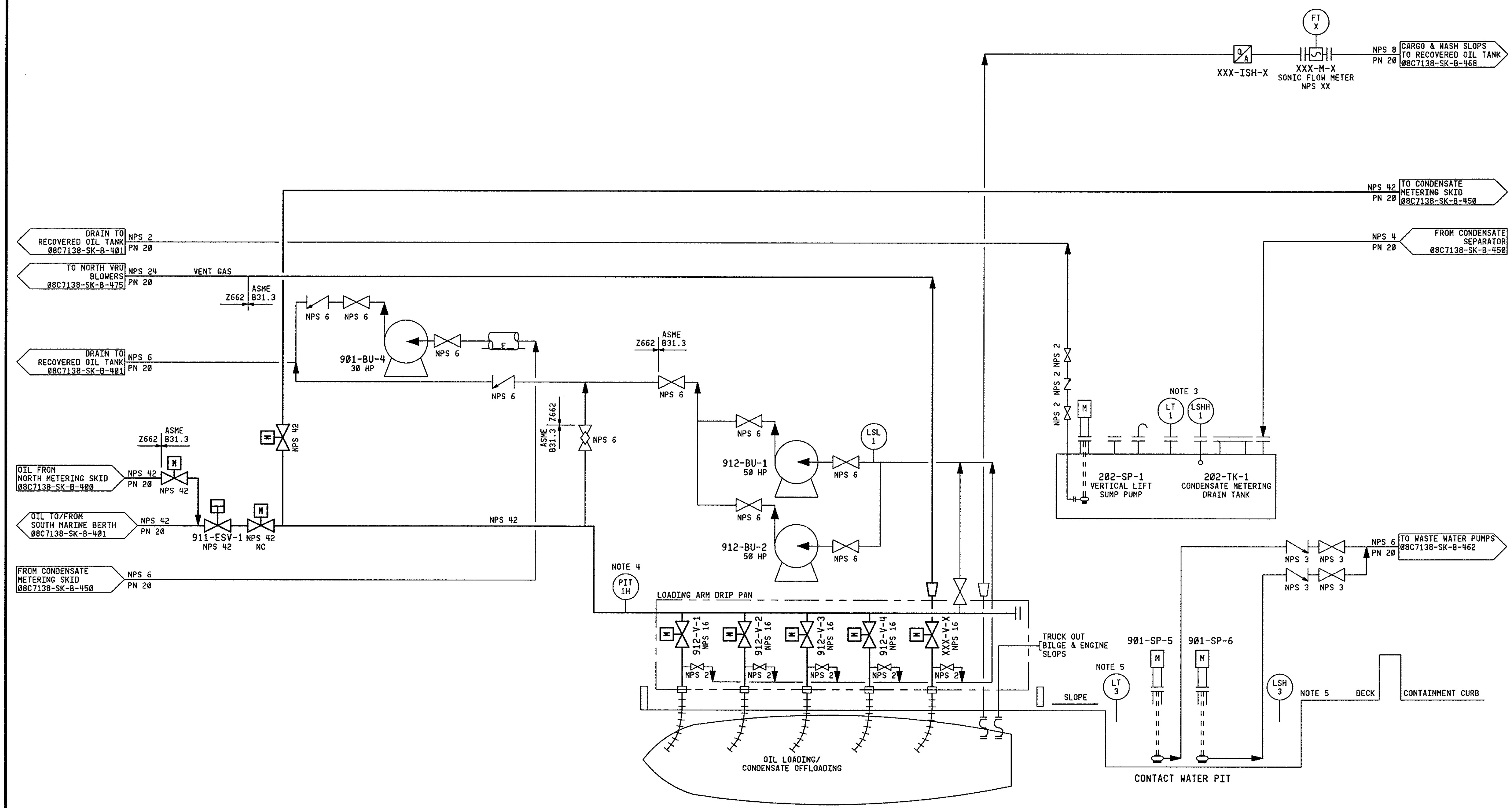
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
SOUTH MARINE BERTH
PROCESS FLOW DIAGRAM

DRAWN	ALS	CHECK		APPROVE	
DATE	11 OCT 06	SCALE		APPROVE	

08C7138-SK-B-401 I-13



NOTES:

1. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "KM" FOR KITIMAT MARINE.
2. ALL PIPING IS PN 20 UNLESS OTHERWISE NOTED.
3. PREFIX FOR ALL CONTROL/MEASURMENT INSTRUMENTS IS "202-"
4. PREFIX FOR ALL CONTROL/MEASURMENT INSTRUMENTS IS "912-"
5. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "901-"
6. FUNCTIONAL SYSTEM CODE "912-" INDICATES CONDENSATE RECEIPT.
7. FUNCTIONAL SYSTEM CODE "901-" INDICATES WATER SEPARATION OR PRODUCT RECOVERY.
8. FUNCTIONAL SYSTEM CODE "202-" INDICATES CONDENSATE COMMODITY TRANSFER.
9. EACH PUMP AND PUMP MOTOR UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
10. BUILDINGS AND CONFINED SPACES ARE EQUIPPED WITH A HEAT DETECTOR, SMOKE DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
11. SIX DISTINCT SYSTEMS EXIST ON SHIP UNLOADING BERTH: DOCKING AID SYSTEM, CENTRAL INTEGRATED MONITORING, ELECTRIC REMOTE RELEASE, MOORING UNLOADING MONITORING, ENVIRONMENTAL MONITORING, AND A CAMERA SYSTEM.
12. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
13. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	04 SEP 09 RTM	

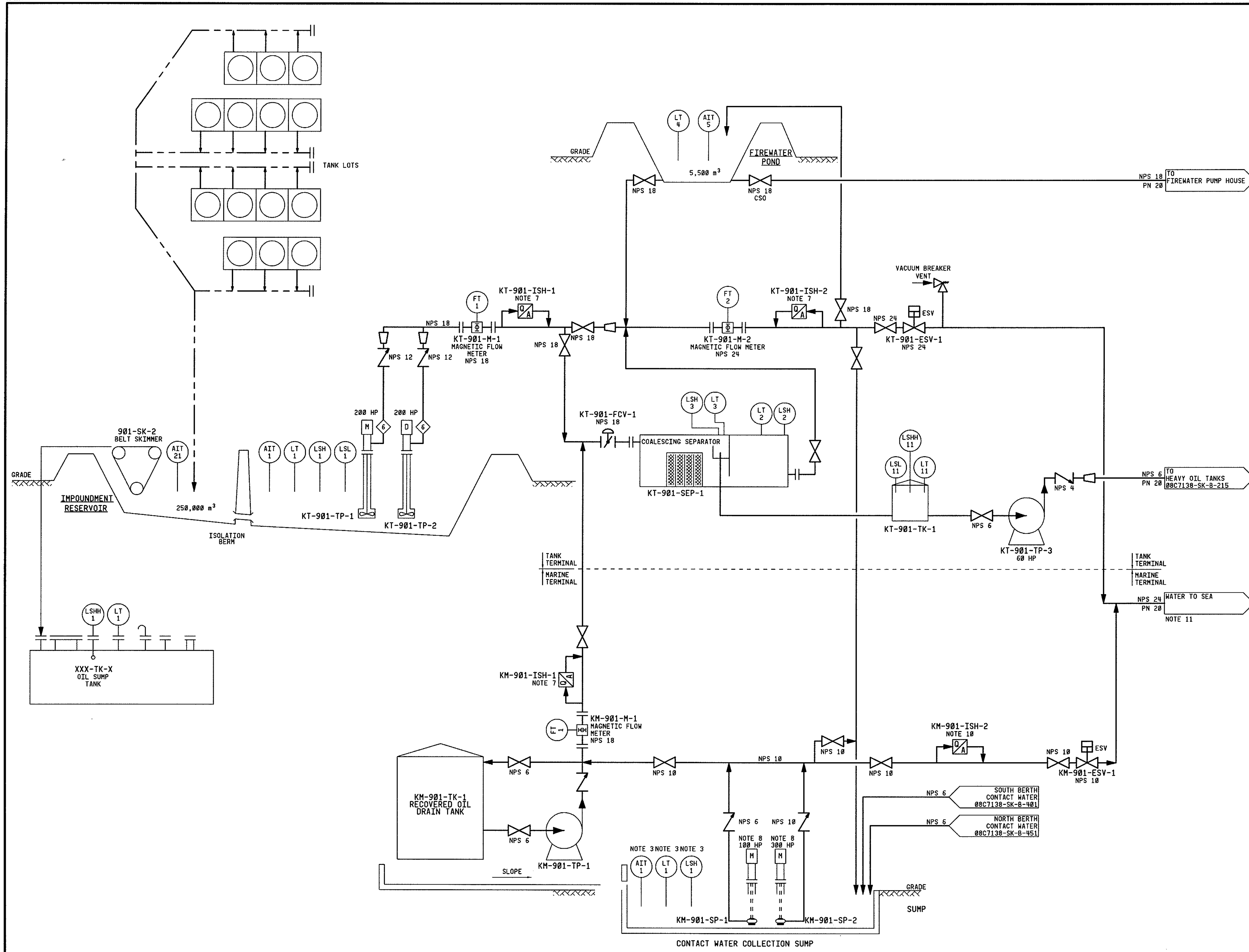
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
NORTH MARINE BERTH
PROCESS FLOW DIAGRAM

DRAWN	ALS	CHECK		APPROVE	
DATE	11 OCT 06	SCALE	NTS	APPROVE	

08C7138-SK-B-451 I-14



NOTES:

1. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "901-".
2. FUNCTIONAL SYSTEM CODE "901-" INDICATES WATER SEPARATION OR PRODUCT RECOVERY.
3. LOCATION CODE FOR ALL NOTED INSTRUMENTATION, EQUIPMENT, ETC. IS "KM-" FOR KITIMAT MARINE.
4. LOCATION CODE FOR REMAINING INSTRUMENTATION, EQUIPMENT, ETC. IS "KT-" FOR KITIMAT TANKAGE AREA.
5. EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
6. EACH PUMP AND PUMP MOTOR UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
7. WATER QUALITY ANALYTICAL INSTRUMENTS FOR WATER HEADING TO SEA INCLUDE: AN ORGANICS ANALYZER (TOTAL ORGANIC CARBON AND CHEMICAL OXYGEN DEMAND), OIL IN WATER ANALYZER, AND INSTRUMENTS FOR OBTAINING MANUAL SAMPLES.
8. PUMP CONTROLLED BY A MAGNETIC DRIVE.
9. BUILDING AND CONFINED SPACES ARE EQUIPPED WITH HEAT DETECTOR, SMOKE DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
10. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.
11. WATER DISCHARGED AWAY FROM BERTH THROUGH SLOTTED PIPE.

LEGEND:

— — — TANK LOT DRAINAGE BY CIVIL. (IE. DITCH, CULVERT AND/OR PIPE)

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY (GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	01 FEB 10 RTM	

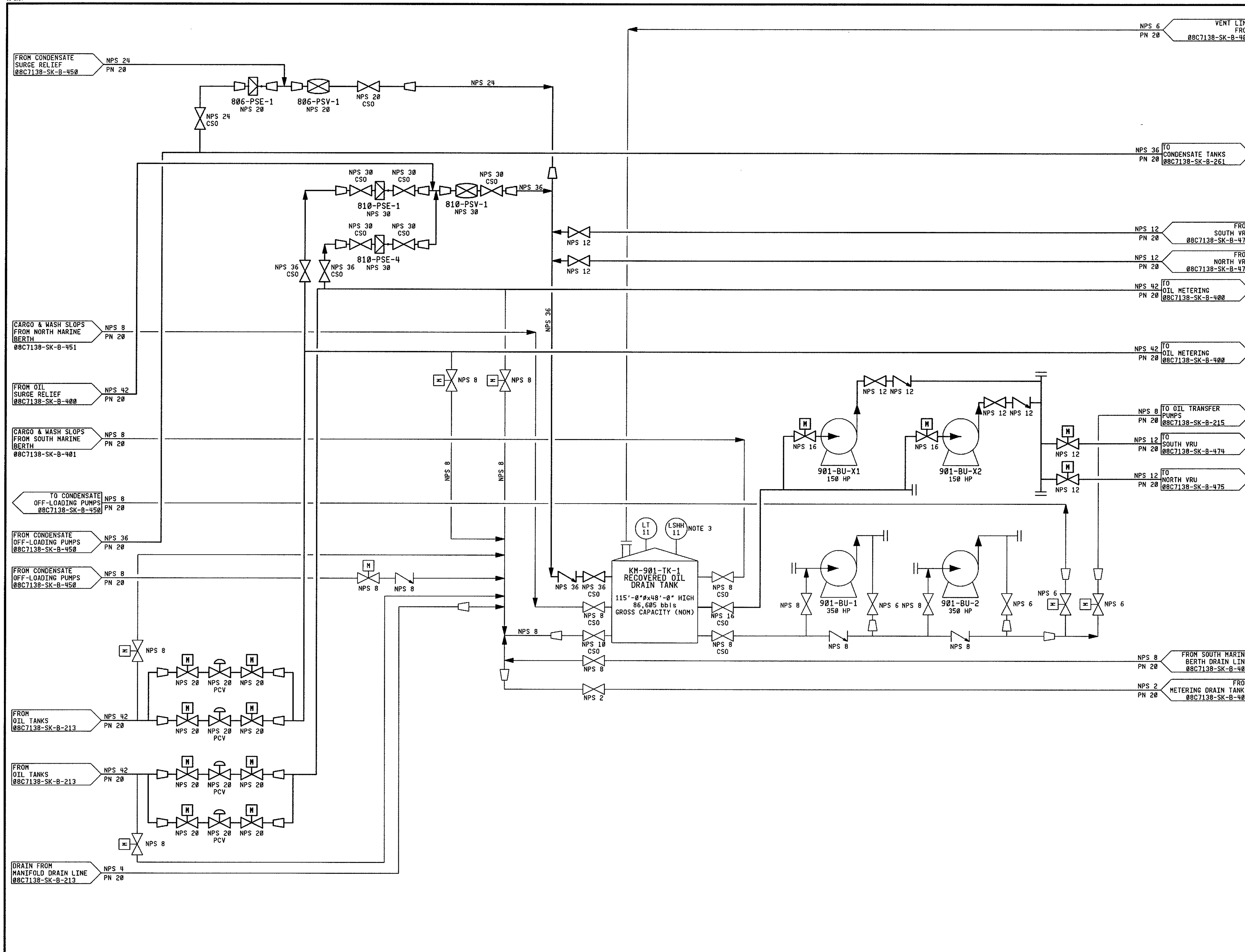
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
SITE WATER SYSTEM
PROCESS FLOW DIAGRAM

DRAWN	RM	CHECK		APPROVE	
DATE	17 MAY 06	SCALE		APPROVE	

08C7138-SK-B-462



NOTES:

1. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "KM" FOR KITIMAT MARINE.
2. ALL PIPING IS PN 20 UNLESS OTHERWISE NOTED.
3. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS "901-".
4. FUNCTIONAL SYSTEM CODE "901-" INDICATES WATER SEPARATION OR PRODUCT RECOVERY.
5. FUNCTIONAL SYSTEM CODE "806-" INDICATES EMERGENCY PRODUCT RELIEF.
6. FUNCTIONAL SYSTEM CODE "810-" INDICATES EMERGENCY OIL RELIEF.
7. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
8. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

HOLDS:

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	26 MAY 09 RTM	

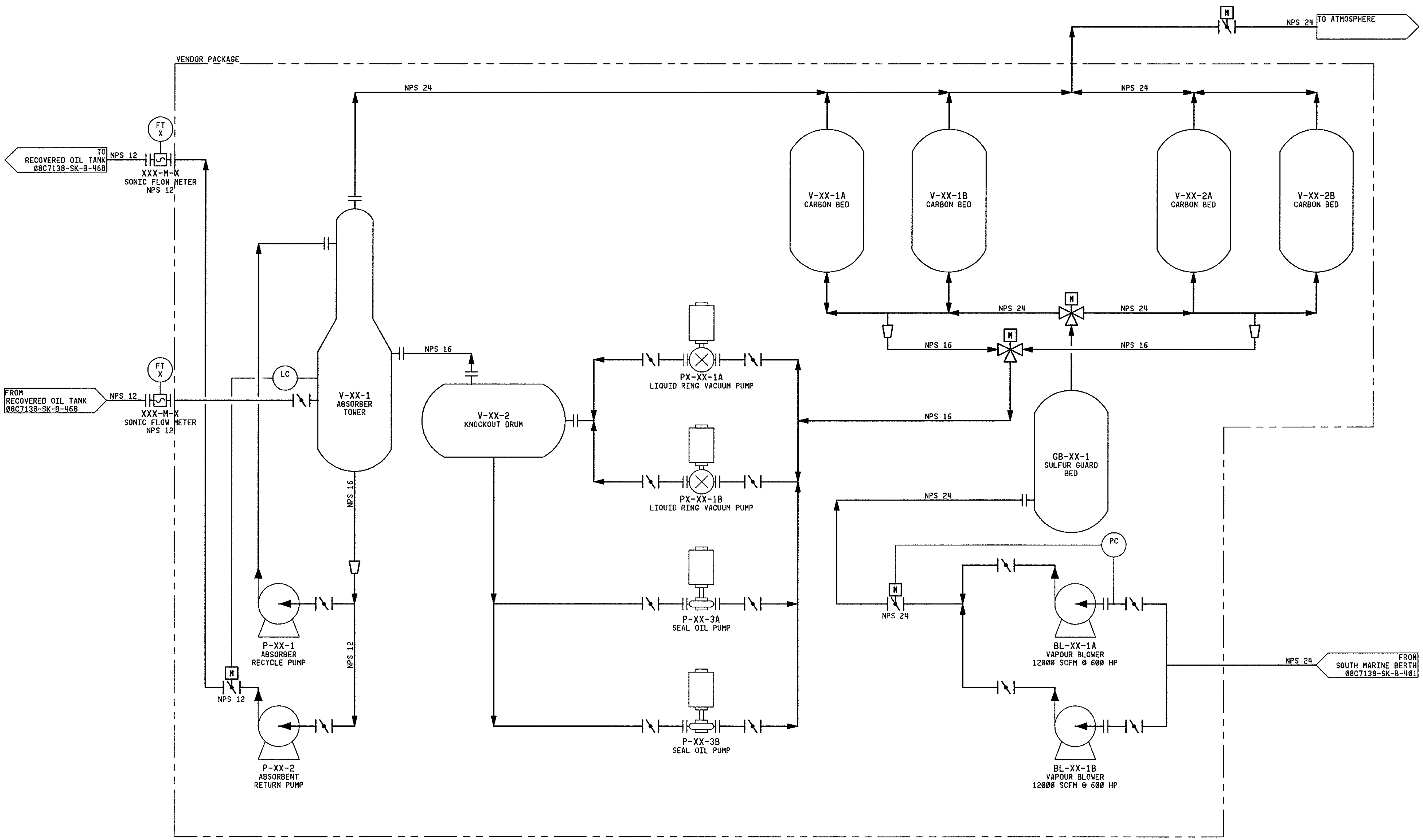
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
DRAIN AND RECOVERY TANKS
PROCESS FLOW DIAGRAM

DRAWN ALS	CHECK	APPROVE	
DATE 11 OCT 06	SCALE	APPROVE	

08C7138-SK-B-468 I-16



NOTES:

1. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "KM" FOR KITIMAT MARINE.
2. ALL PIPING IS PN 20 UNLESS OTHERWISE NOTED.
3. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS TO BE DEFINED IN A LATER PHASE.
4. FUNCTIONAL SYSTEM CODE IS TO BE DEFINED IN A LATER PHASE.
5. EACH PUMP, PUMP MOTOR UNIT, AND BLOWER UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
6. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
7. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR REVIEW	26 MAY 09 RTM	

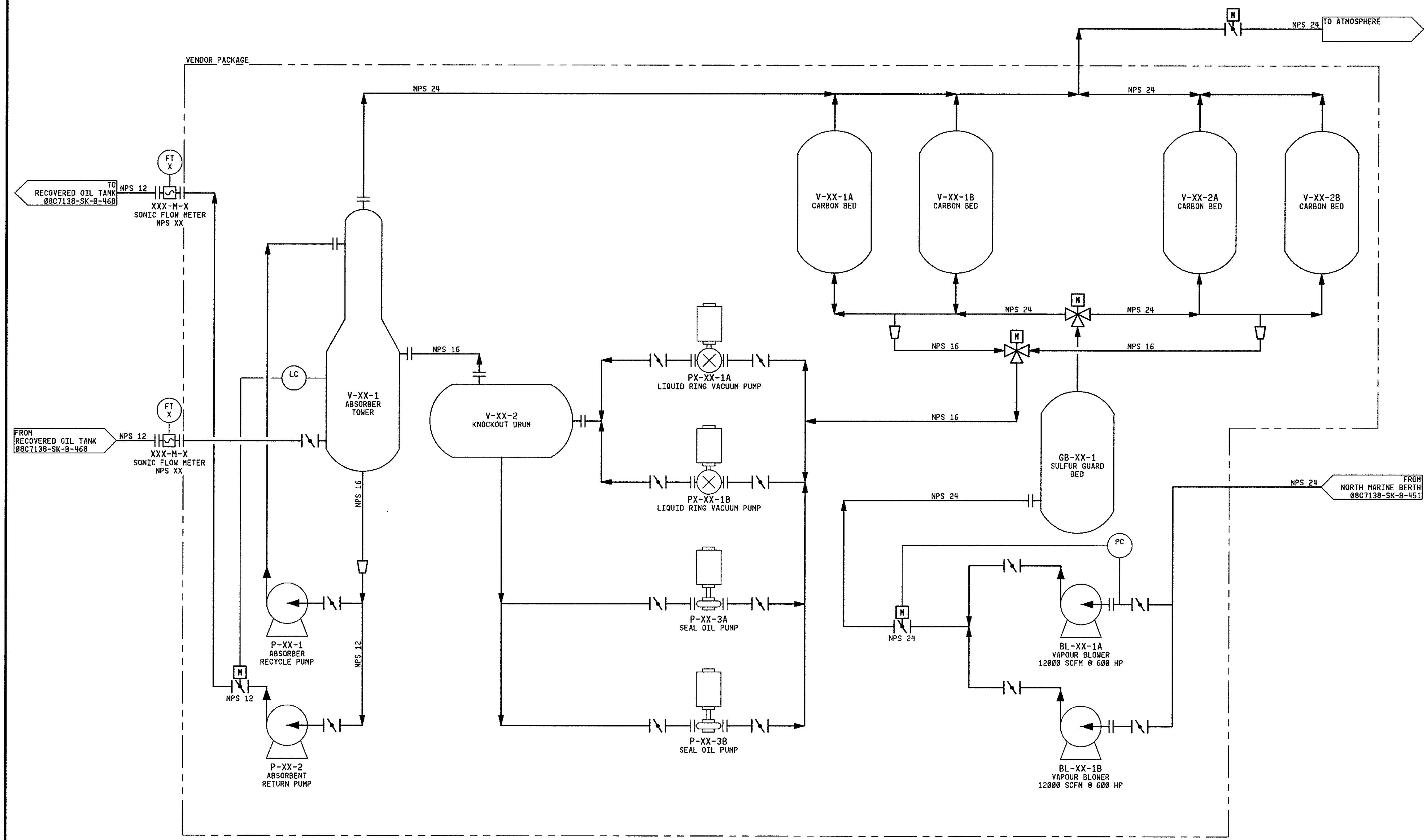
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
SOUTH VAPOUR RECOVERY UNIT
PROCESS FLOW DIAGRAM

DRAWN	RTM	CHECK		APPROVE	
DATE	04 MAY 09	SCALE		APPROVE	

08C7138-SK-B-474



NOTES:

1. LOCATION CODE FOR ALL INSTRUMENTS, EQUIPMENT, ETC. IS "KM" FOR KITIMAT MARINE.
2. ALL PIPING IS PN 20 UNLESS OTHERWISE NOTED.
3. PREFIX FOR ALL CONTROL/MEASUREMENT INSTRUMENTS IS TO BE DEFINED IN A LATER PHASE.
4. FUNCTIONAL SYSTEM CODE IS TO BE DEFINED IN A LATER PHASE.
5. EACH PUMP, PUMP MOTOR UNIT, AND BLOWER UNIT INCLUDES A HEAT DETECTOR, UV/IR FLAME DETECTOR, H2S DETECTOR, AND LEL DETECTOR.
6. ALL EQUIPMENT AND LINE SIZES ARE PRELIMINARY.
7. PRELIMINARY DRAWING TO BE FURTHER DEVELOPED IN DETAILED DESIGN.

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
B	ISSUED FOR REVIEW	26 MAY 09 RTM	

NO	REVISION	DATE/BY	APPROVE

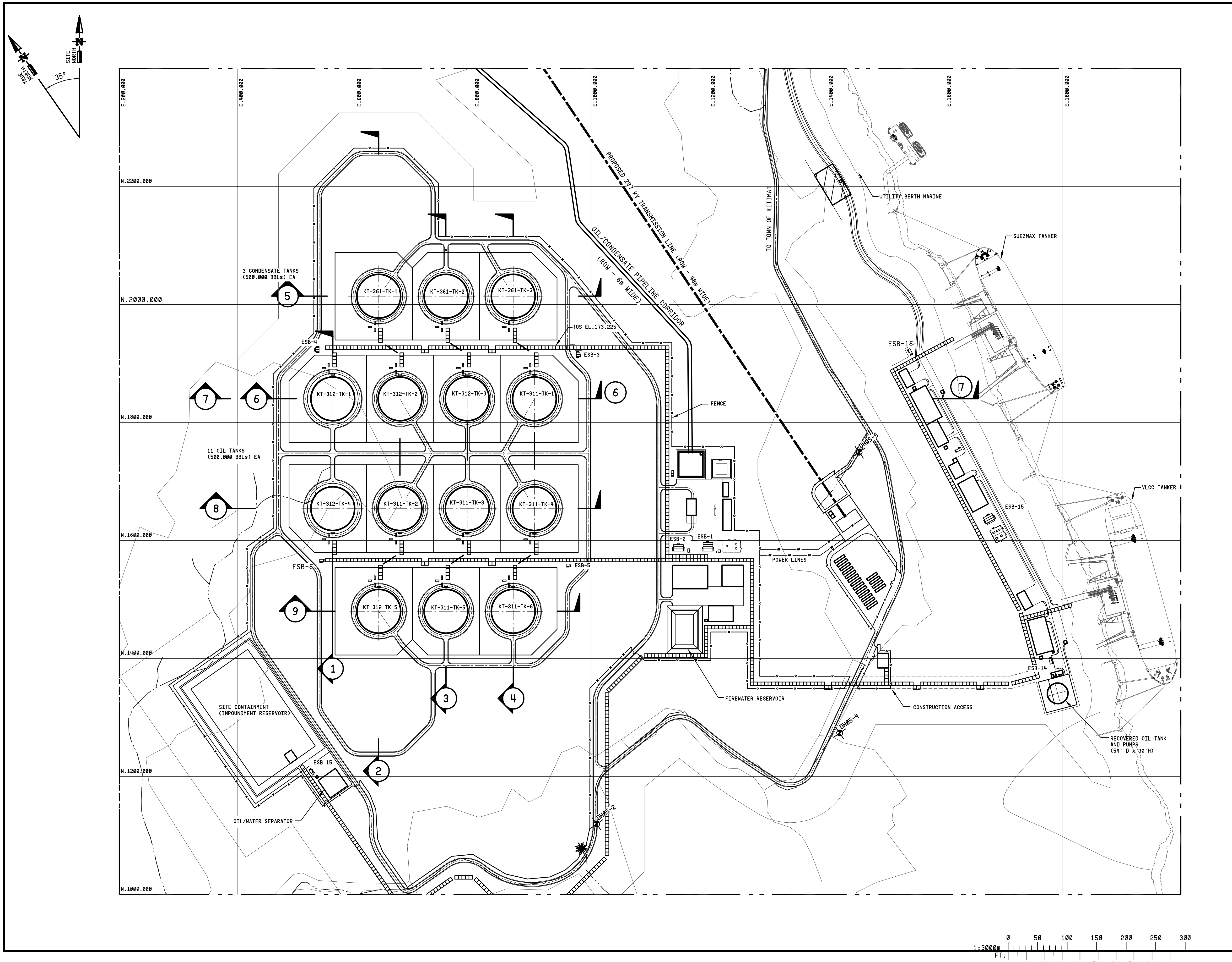
ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
NORTH VAPOUR RECOVERY UNIT
PROCESS FLOW DIAGRAM

DRAWN RTM	CHECK	APPROVE
DATE 04 MAY 09	SCALE	APPROVE

08C7138-SK-B-475

I-18



NOTES
1. ALL ELEVATIONS SHOWN ON THIS DRAWING ARE GEODETIC.
2. PLANT DATUM 0,0 IS LOCATED IN UTM ZONE 9 5977m NORTH, 516.5m EAST.

LEGEND

	EXISTING LOGGING ROAD
KT-311	DILBIT TANK DESIGNATION
KT-312	SYNTHETIC OIL TANK DESIGNATION
KT-361	CONDENSATE TANK DESIGNATION

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	26 JAN 10 TT	

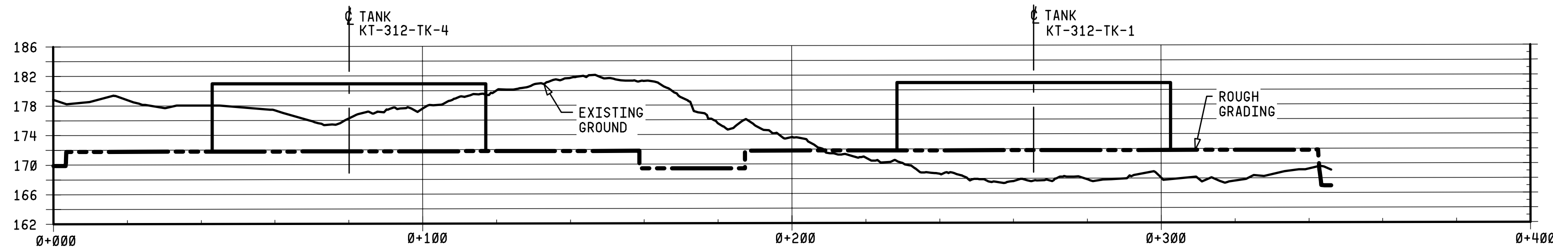
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

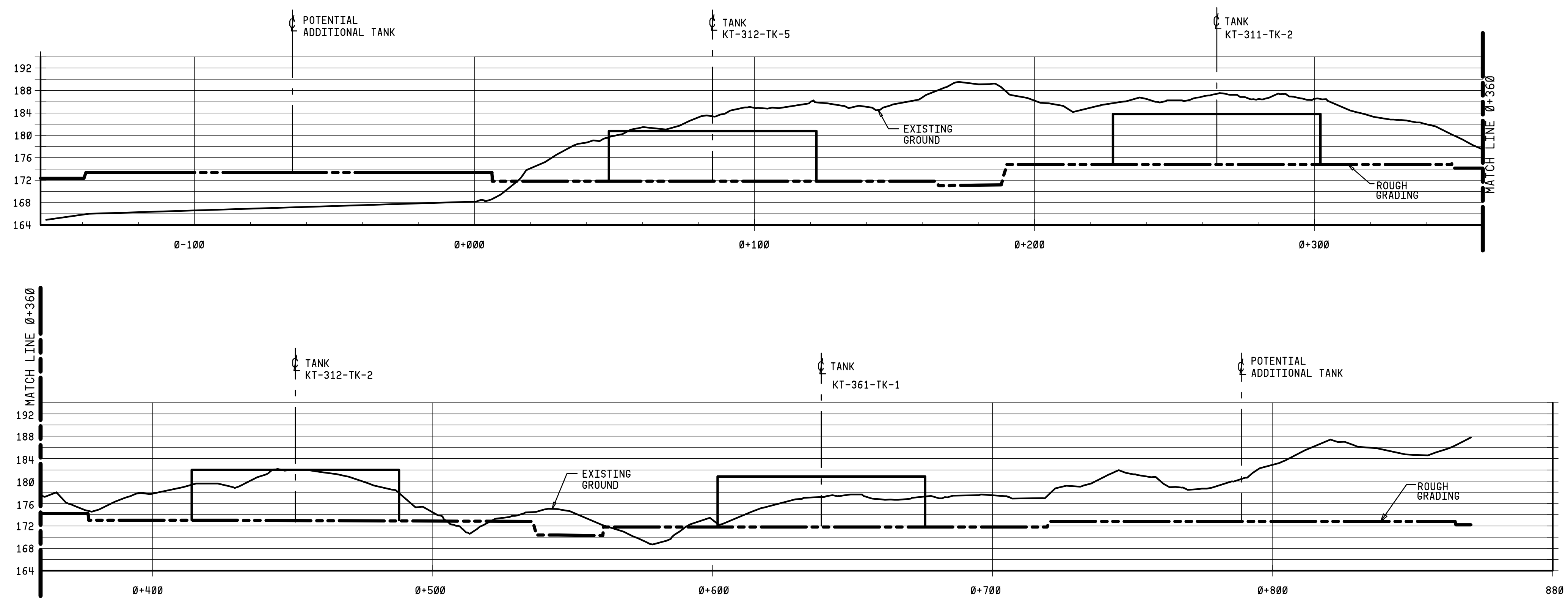
ENBRIDGE NORTHEN GATEWAY PROJECT
KITIMAT TERMINAL
CIVIL SECTIONS LAYOUT
CIVIL SECTIONS PLOT PLAN

DRAWN	TT	CHECK		APPROVE
DATE	21 JAN 10	SCALE	1:3000	APPROVE

08C7138-SK-A-221 | I-19



SECTION 1
HZ: 1:1000
V: 1:500



SECTION 2
HZ: 1:1000
V: 1:500

NOTE: VERTICAL SCALE EXAGGERATED 2 TIMES.

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

		DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	26 JAN 10 TT	

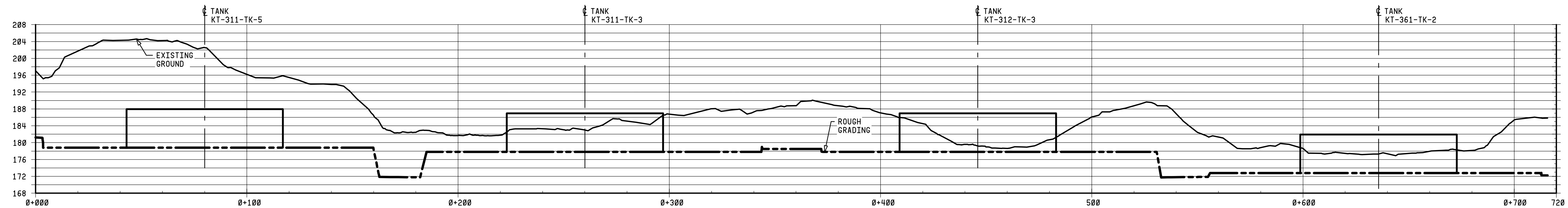
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

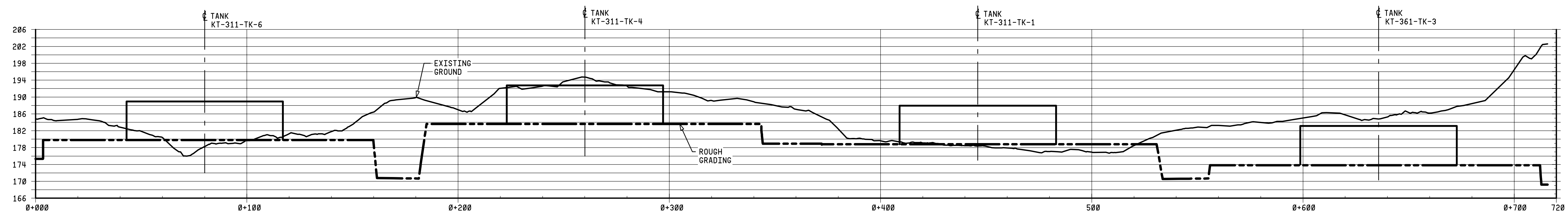
ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
ROUGH GRADING
PROFILE - SECTIONS 1 & 2

DRAWN TT	CHECK	APPROVE
DATE 21 JAN 10	SCALE AS SHOWN	APPROVE

08C7138-SK-A-222 I-20



3 SECTION
HZ: 1:1000
V: 1:500



4 SECTION
HZ: 1:1000
V: 1:500

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - Ø8C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	26 JAN 10 TT	

NOTE: VERTICAL SCALE EXAGGERATED BY 2 TIMES.

NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
ROUGH GRADING
PROFILE - SECTIONS 3 & 4

DRAWN TT	CHECK	APPROVE
DATE 21 JAN 10	SCALE AS SHOWN	APPROVE

Ø8C7138-SK-A-223 | I-21

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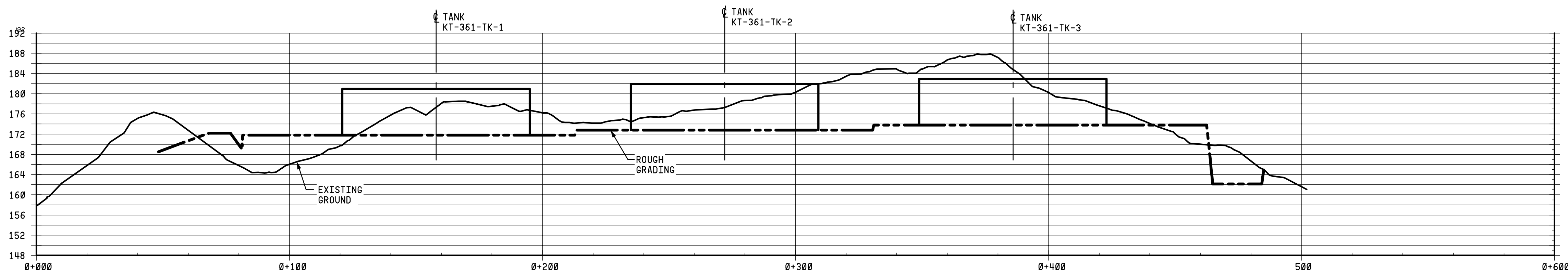
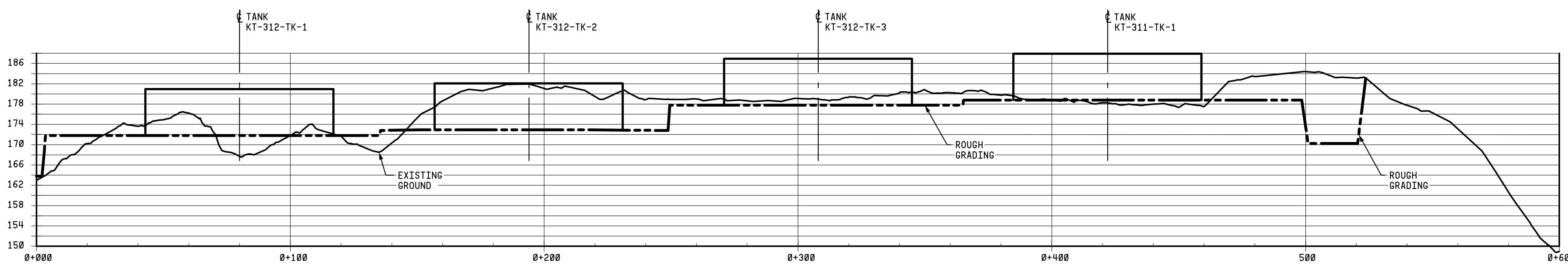


5 SECTION
HZ: 1:1000
V: 1:500



6 SECTION
HZ: 1:1000
V: 1:500

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	26 JAN 10 TT	

NOTE: VERTICAL SCALE EXAGGERATED 2 TIMES.

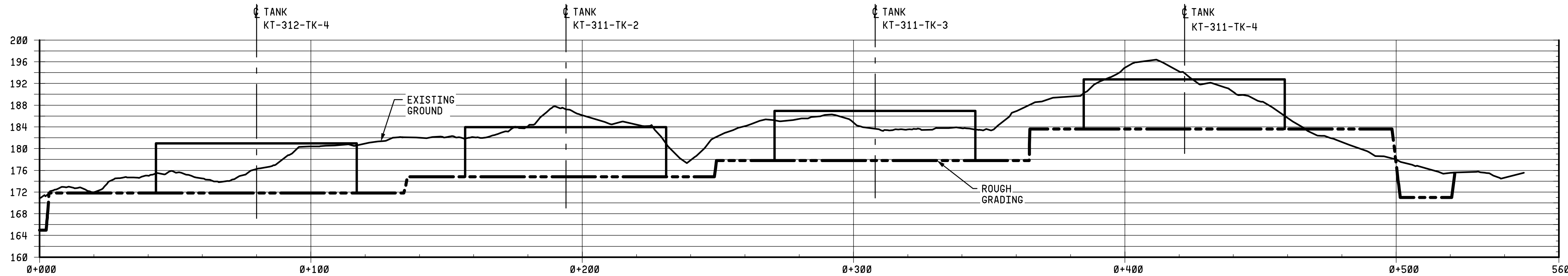
NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

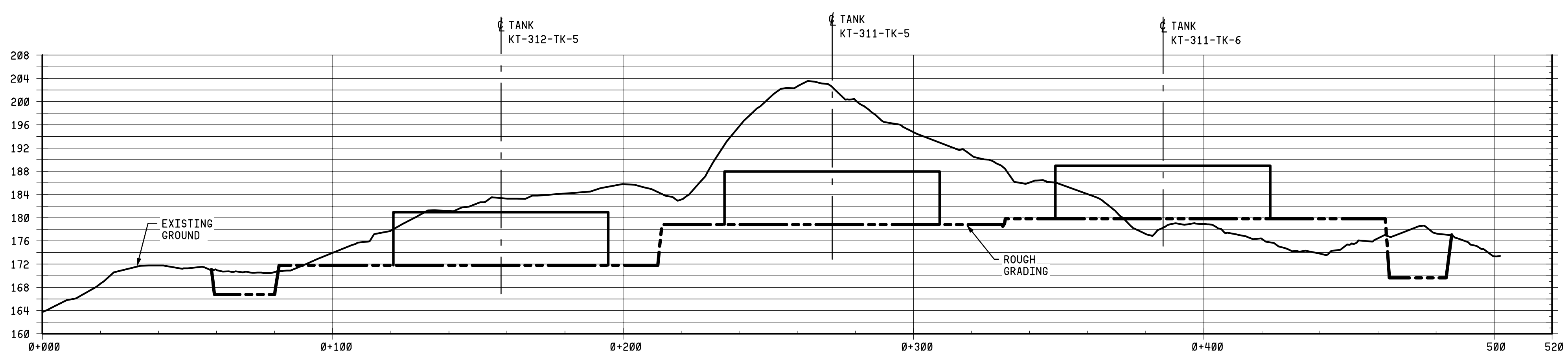
ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
ROUGH GRADING
PROFILE - SECTIONS 5 & 6

DRAWN TT	CHECK	APPROVE
DATE 21 JAN 10	SCALE AS SHOWN	APPROVE

08C7138-SK-A-224 | I-22



8 SECTION
HZ: 1:1000
V: 1:500



9 SECTION
HZ: 1:1000
V: 1:500

NOTE: VERTICAL SCALE EXAGGERATED 2 TIMES.

Colt Engineering Corporation
FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	26 JAN 10 TT	

NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
ROUGH GRADING
PROFILE - SECTIONS 8 & 9

DRAWN TT	CHECK	APPROVE
DATE 21 JAN 10	SCALE AS SHOWN	APPROVE

08C7138-SK-A-225 | I-23

01-2007

7 SECTION
HZ: 1:2000
V: 1:1000

NOTE: VERTICAL SCALE EXAGGERATED 2 TIMES

Colt Engineering Corporation

FOR COLT INTERNAL REVISIONS ONLY
(GATEWAY NEB APPLICATION - 08C7138)

NO	REVISION	DATE/BY	APP
A	ISSUED FOR NEB APPLICATION	26 JAN 10 TT	

NO	REVISION	DATE/BY	APPROVE

ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT
KITIMAT TERMINAL
ROUGH GRADING
PROFILE - SECTION 7

DRAWN	TT	CHECK		APPROVE	
DATE	21 JAN 10	SCALE	AS SHOWN	APPROVE	

08C7138-SK-A-226 | I-24

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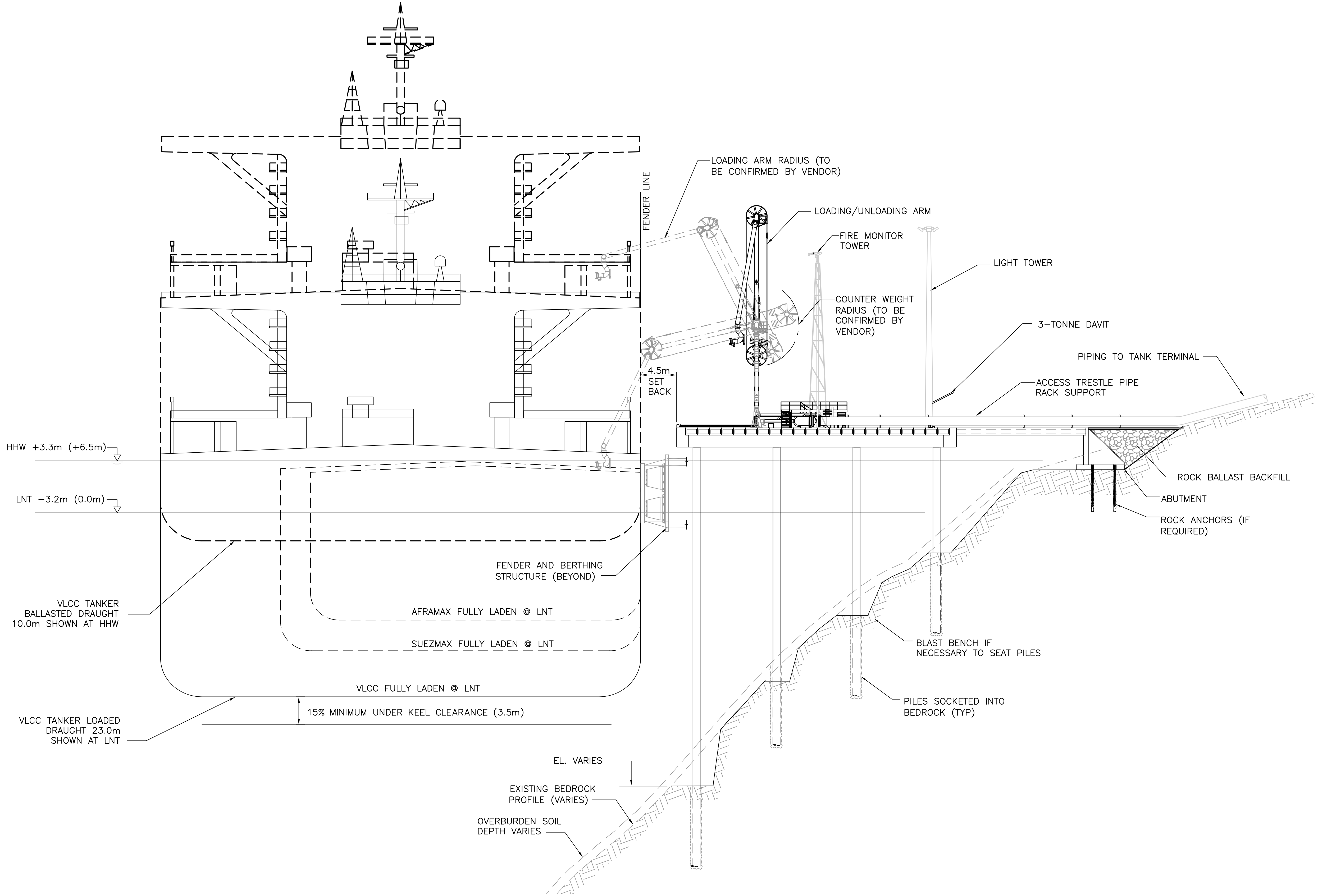


A / 003 — A / 003A — SECTION

NOTE:

1. ELEVATIONS ARE TO GEODETIC DATUM (HYDROGRAPHIC ELEVATIONS IN BRACKETS)

5m 0m 5m 10m

REVISION	DESCRIPTION	DATE	Dr'n	Ch'd
D	ISSUED FOR NEB VOLUME 3	JAN 29/10	JL	RB
C	ISSUED FOR TERMPOL SUBMISSION	JAN 15/10	JL	RB
B	ISSUED FOR NEB VOLUME 3	NOV 10/09	JL	RB
A	ISSUED FOR TERMPOL DRAFT REPORT	MAY 11/09	JL	RB

CLIENT: ENBRIDGE NORTHERN GATEWAY PIPELINES

MOFFATT & NICHOL
777 WEST BROADWAY, SUITE 301
VANCOUVER, BC, CANADA, V5Z 4J7
604-707-9004

DESIGN	DRAWN	CHK'D	APP'D
CR	JL		–

DATE: JAN. 26, 09 — DRAWING NUMBER: 5743-03-007

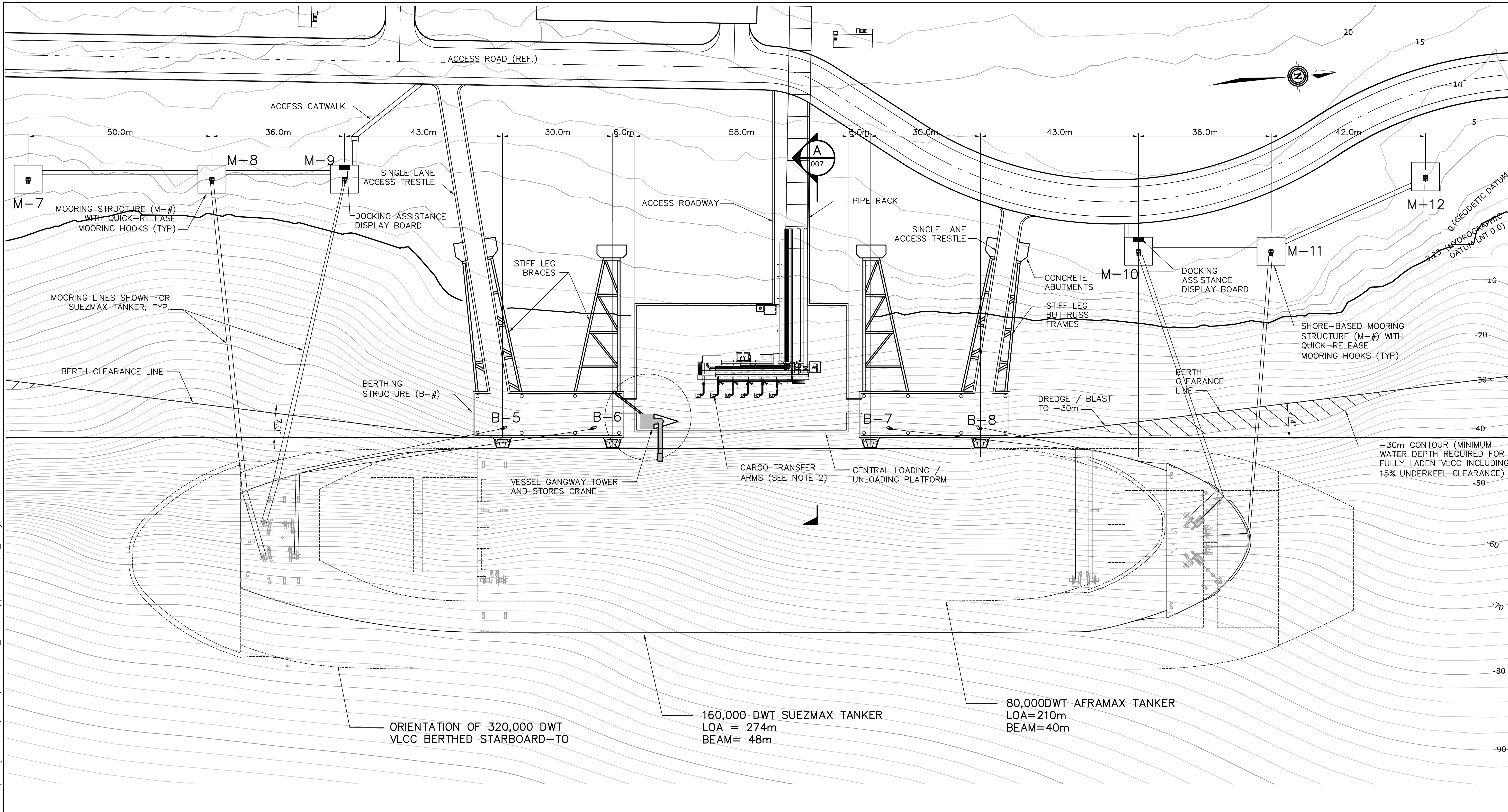
KITIMAT MARINE TERMINAL BERTHS

PRELIMINARY CENTRAL PLATFORM
PILE AND DECK STRUCTURES
TYPICAL SECTION

SCALE: AS SHOWN

DRAWING: I-25

DATE: 2010/02/17 - 8:34am
PATH: P:\5743-03 Northern Gateway Termpol Studies\CADD\Submittals\ISSUED\2010-02-17_I-25&26\5743-03-007.dwg



NOTE:

1. ELEVATIONS ARE TO GEODETIC DATUM.
2. LOADING LAYOUT FOR LOADING ARMS AND OTHER TOP SIDES EQUIPMENT BASED ON COLT ENGINEERING DRAWING 08C7138-SK-A-472 REV D
3. THE PRECISE BERTH LOCATIONS AND ALIGNMENTS ARE CONSIDERED PRELIMINARY, SUBJECT TO REFINEMENT AND OPTIMIZATION DURING THE DETAILED DESIGN PROCESS. THE FINAL POSITION OF MOORING STRUCTURES IS SIMILARLY SUBJECT TO CHANGE AND WILL BE VALIDATED THROUGH DETAILED MOORING FORCE ANALYSES AT A LATER STAGE OF THE PROJECT.

10m 0m 10m 20m

REVISION	DESCRIPTION	DATE	Dr'n	Ch'd
D	ISSUED FOR NEB VOLUME 3	JAN 29/10	JL	RB
C	ISSUED FOR TERMPOL SUBMISSION	JAN 15/10	JL	RB
B	REVISED MOORING LOCATIONS	NOV 10/09	JL	RB
A	ISSUED FOR TERMPOL DRAFT REPORT	MAY 11/09	JL	RB

CLIENT:
ENBRIDGE NORTHERN GATEWAY PIPELINES

MOFFATT & NICHOL
777 WEST BROADWAY, SUITE 301
VANCOUVER, BC, CANADA, V5Z 4J7
604-707-9004

DESIGN RB | DRAWN JL | CHK'D | APP'D –
DATE JAN. 26, 09 | DRAWING NUMBER 5743-03-004-A

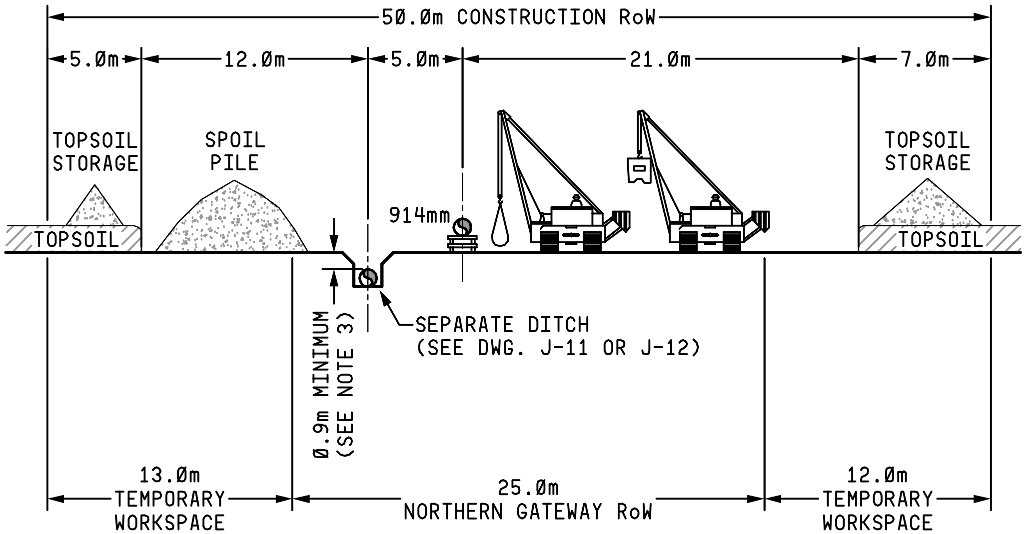
KITIMAT MARINE TERMINAL BERTHS
PRELIMINARY GENERAL ARRANGEMENT
NORTH BERTH
STIFF LEG BRACE OPTION

SCALE AS SHOWN
DRAWING I-26

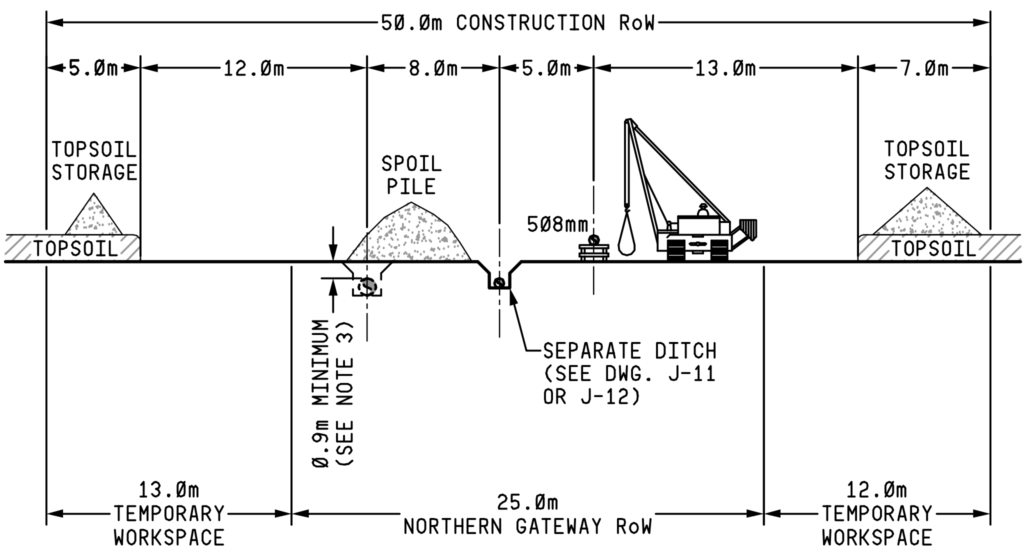
DATE: 2010/02/17 - 8:35am
PATH: P:\5743-03 Northern Gateway Termpol Studies\CADD\Submittals\ISSUED\2010-02-17_I-25&26\5743-03-004_A.dwg

Appendix J Typical Construction Sketches

PHASE 1 INSTALL 914mm (NPS 36) PIPE EAST TO WEST



PHASE 2 INSTALL 508mm (NPS 20) PIPE EAST TO WEST

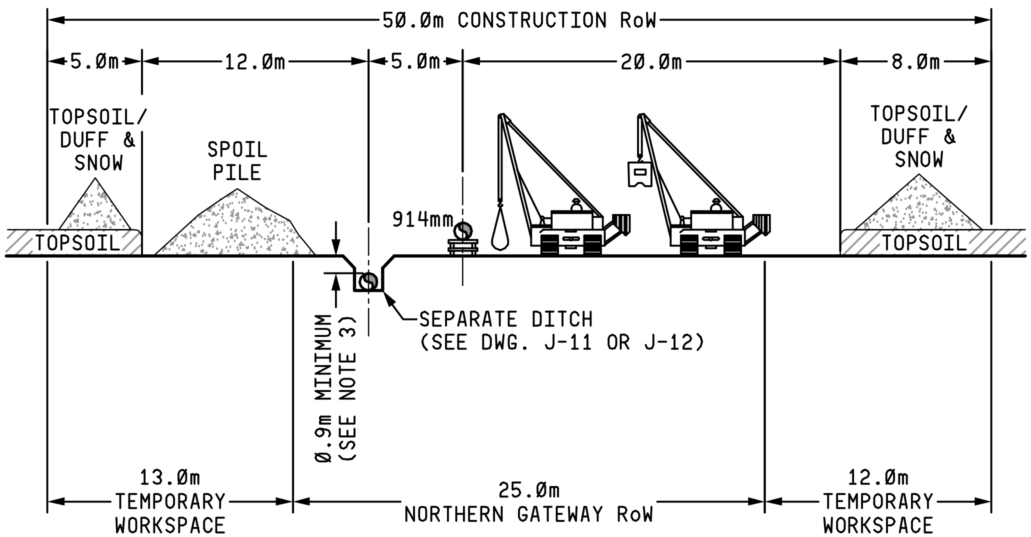


NOTES:

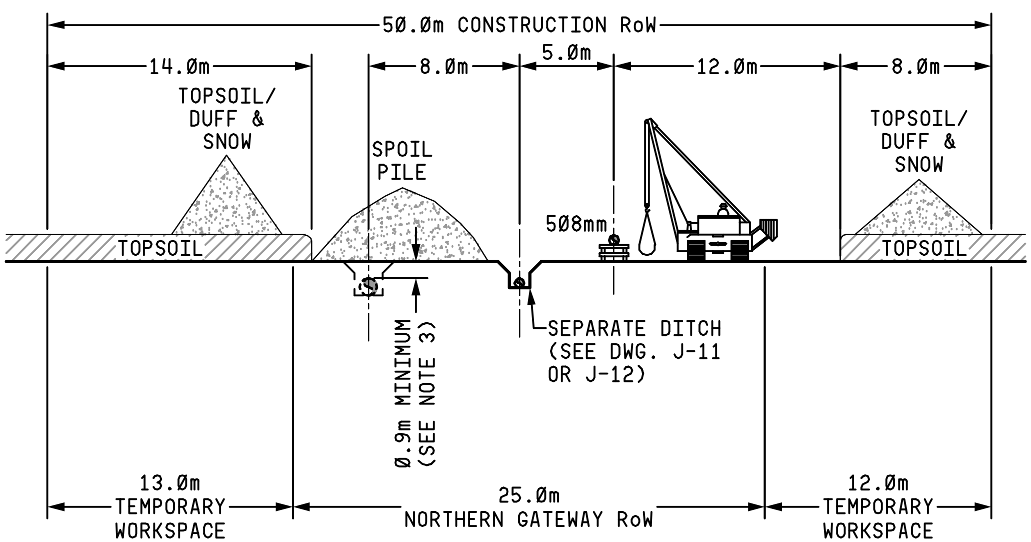
1. DITCH EXCAVATION SHALL BE IN ACCORDANCE WITH OH&S REGULATIONS.
2. STRIP TOPSOIL IN ACCORDANCE WITH ENBRIDGE SPECIFICATIONS.
3. MINIMUM COVER MEASURED FROM GRADE AFTER STRIPPING.
4. MAINTAIN 0.9m COVER OVER BUOYANCY CONTROL ELEMENTS AND OTHER APPURTENANCES MEASURED FROM GRADE AFTER STRIPPING.
5. ASSUME NORMAL BACKFILL.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION C DATE 15 SEP 2009
	RoW CONFIGURATION – SUMMER – DUAL TRENCH	FIGURE NO. J–1

PHASE 1 INSTALL 914mm (NPS 36) PIPE



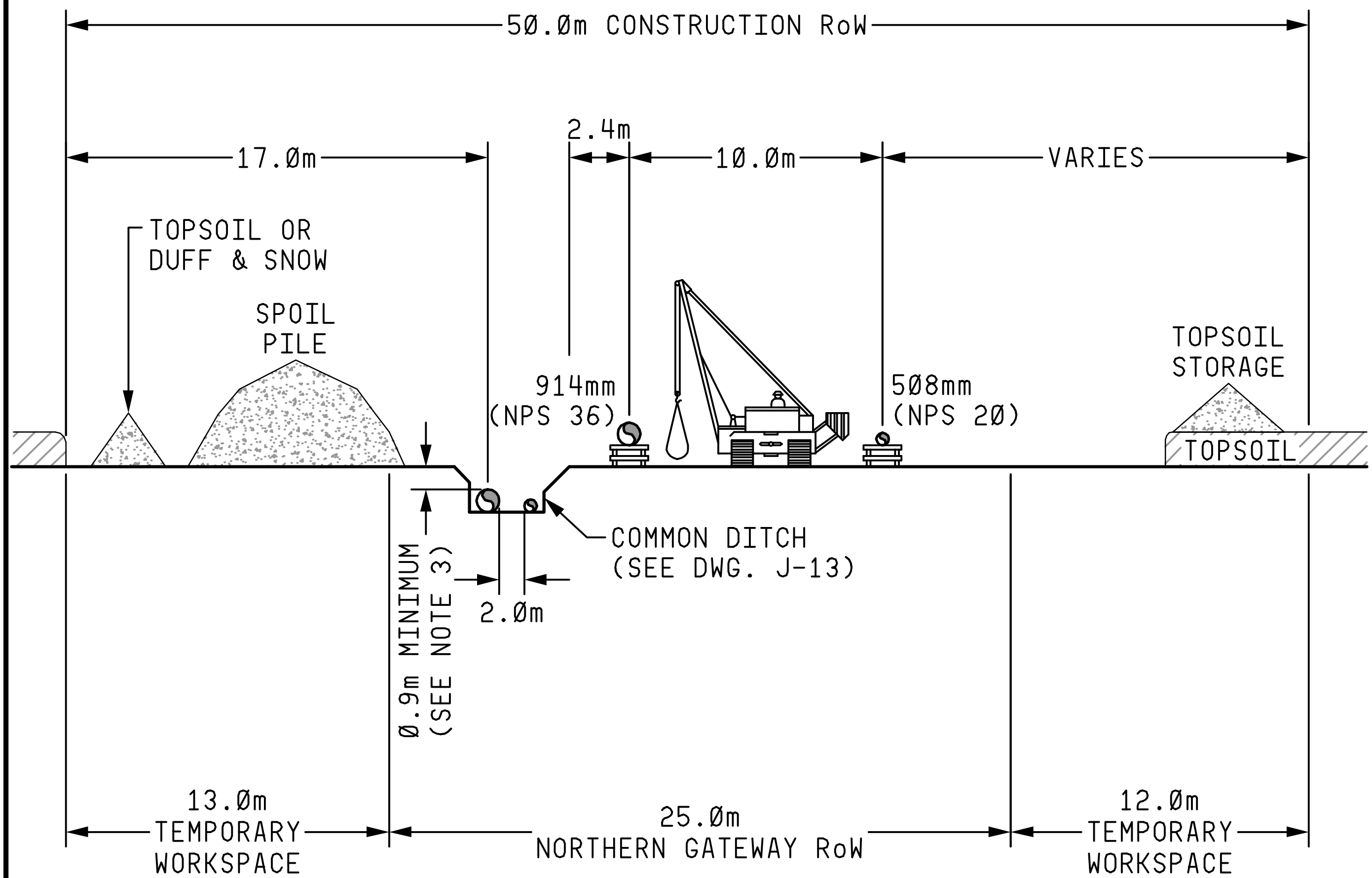
PHASE 2 INSTALL 508mm (NPS 20) PIPE



NOTES:

1. DITCH EXCAVATION SHALL BE IN ACCORDANCE WITH OH&S REGULATIONS.
2. STRIP TOPSOIL IN ACCORDANCE WITH ENBRIDGE SPECIFICATIONS.
3. MINIMUM COVER MEASURED FROM GRADE AFTER STRIPPING.
4. MAINTAIN 0.9m COVER OVER BUOYANCY CONTROL ELEMENTS AND OTHER APPURTENANCES MEASURED FROM GRADE AFTER STRIPPING.
5. ASSUME NORMAL BACKFILL.
6. DURING WINTER CONSTRUCTION THE TOPSOIL/DUFF LAYER MAY NOT BE STRIPPED FROM THE WORKING AREA, WHERE DESIGNATED ON ALIGNMENT SHEETS OR PERMITS.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION C DATE 15 SEP 2009
	RoW CONFIGURATION – WINTER – DUAL TRENCH	FIGURE NO. J-2

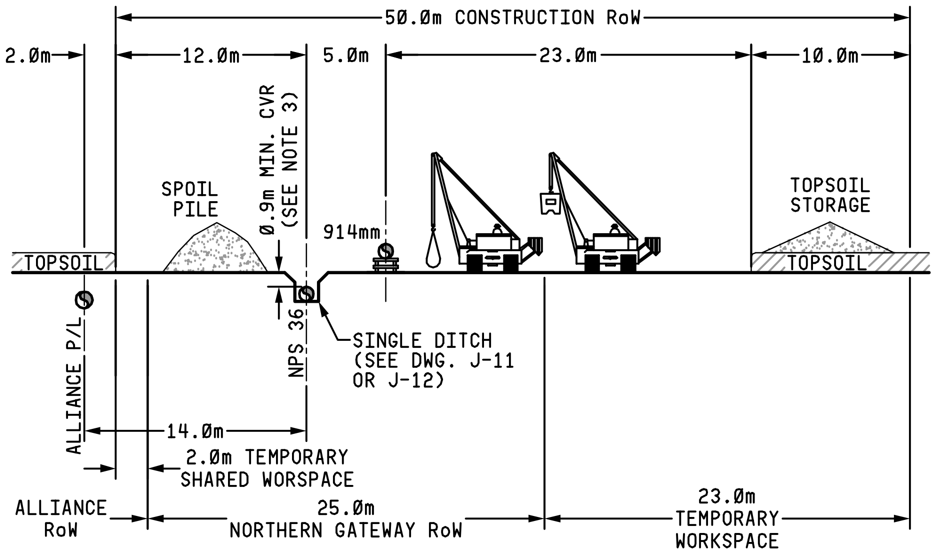


NOTES:

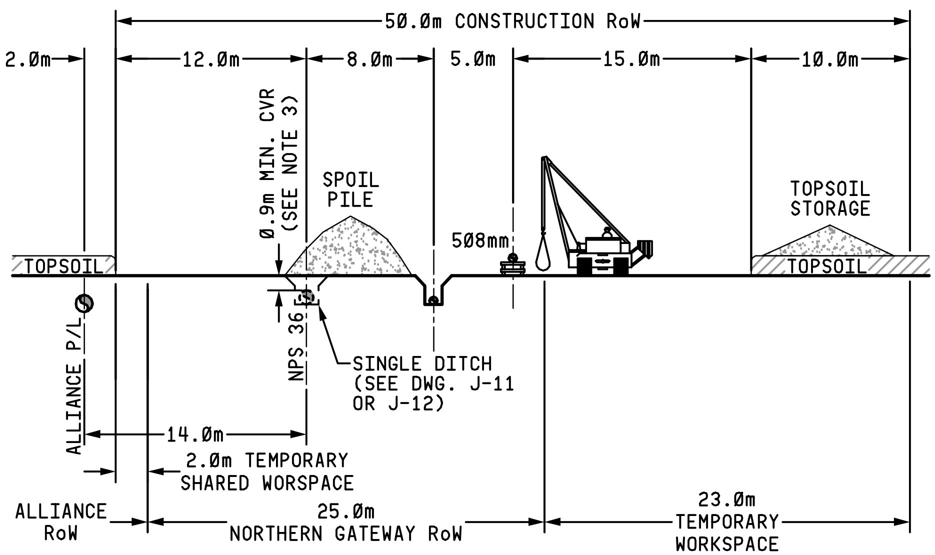
1. DITCH EXCAVATION SHALL BE IN ACCORDANCE WITH OH&S REGULATIONS.
2. STRIP TOPSOIL IN ACCORDANCE WITH ENBRIDGE SPECIFICATIONS.
3. MINIMUM COVER MEASURED FROM GRADE AFTER STRIPPING.
4. MAINTAIN 0.9m COVER OVER BUOYANCY CONTROL ELEMENTS AND OTHER APPURTENANCES MEASURED FROM GRADE AFTER STRIPPING. MINIMUM COVER REQUIREMENT IS REDUCED TO 0.6m THROUGH SOLID ROCK.
5. ASSUME NORMAL BACKFILL.
6. DURING WINTER CONSTRUCTION THE TOPSOIL/DUFF LAYER MAY NOT BE STRIPPED FROM THE WORKING AREA, WHERE DESIGNATED ON ALIGNMENT SHEETS OR PERMITS.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION D DATE 28 AUG 2009
	RIGHT OF WAY CONFIGURATION SUMMER/WINTER–SINGLE TRENCH	FIGURE NO. J–3

PHASE 1 INSTALL 914mm (NPS 36) PIPE



PHASE 2 INSTALL 508mm (NPS 20) PIPE

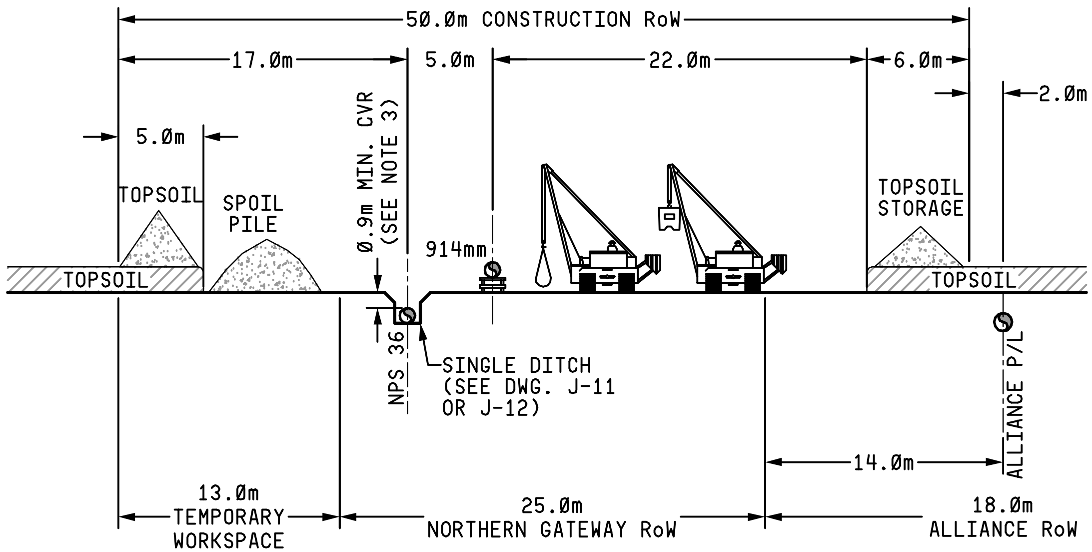


NOTES:

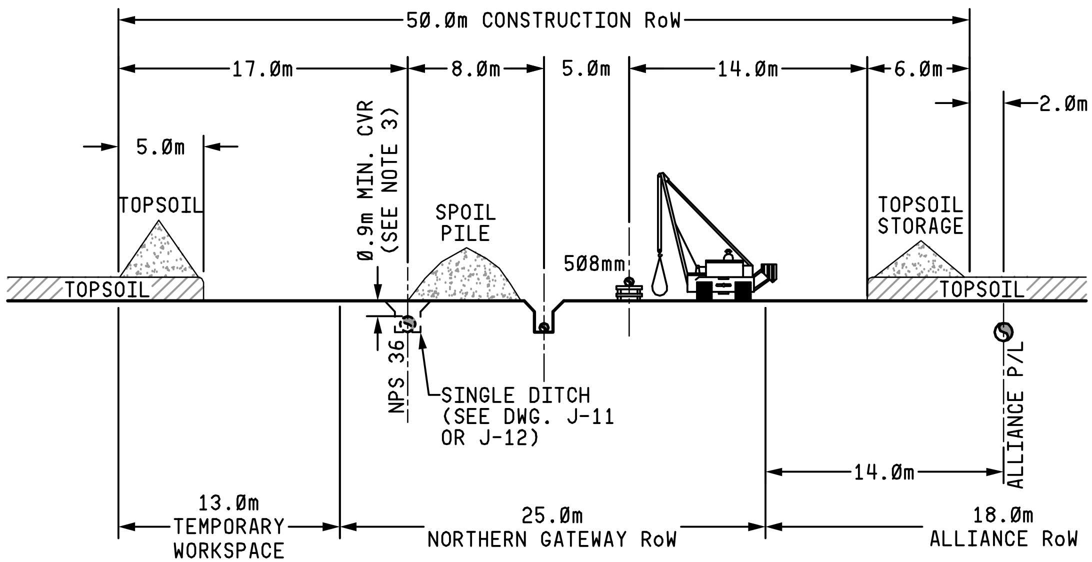
1. DITCH EXCAVATION SHALL BE IN ACCORDANCE WITH OH&S REGULATIONS.
2. STRIP TOPSOIL IN ACCORDANCE WITH ENBRIDGE SPECIFICATIONS.
3. MINIMUM COVER MEASURED FROM GRADE AFTER STRIPPING.
4. MAINTAIN Ø.9m COVER OVER BUOYANCY CONTROL ELEMENTS AND OTHER APPURTENANCES MEASURED FROM GRADE AFTER STRIPPING.
5. ASSUME NORMAL BACKFILL.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION C DATE 15 SEP 2009
	RoW CONFIGURATION DITCH SIDE ADJACENT TO ALLIANCE PIPELINE	FIGURE NO. J-4

PHASE 1 INSTALL 914mm (NPS 36) PIPE



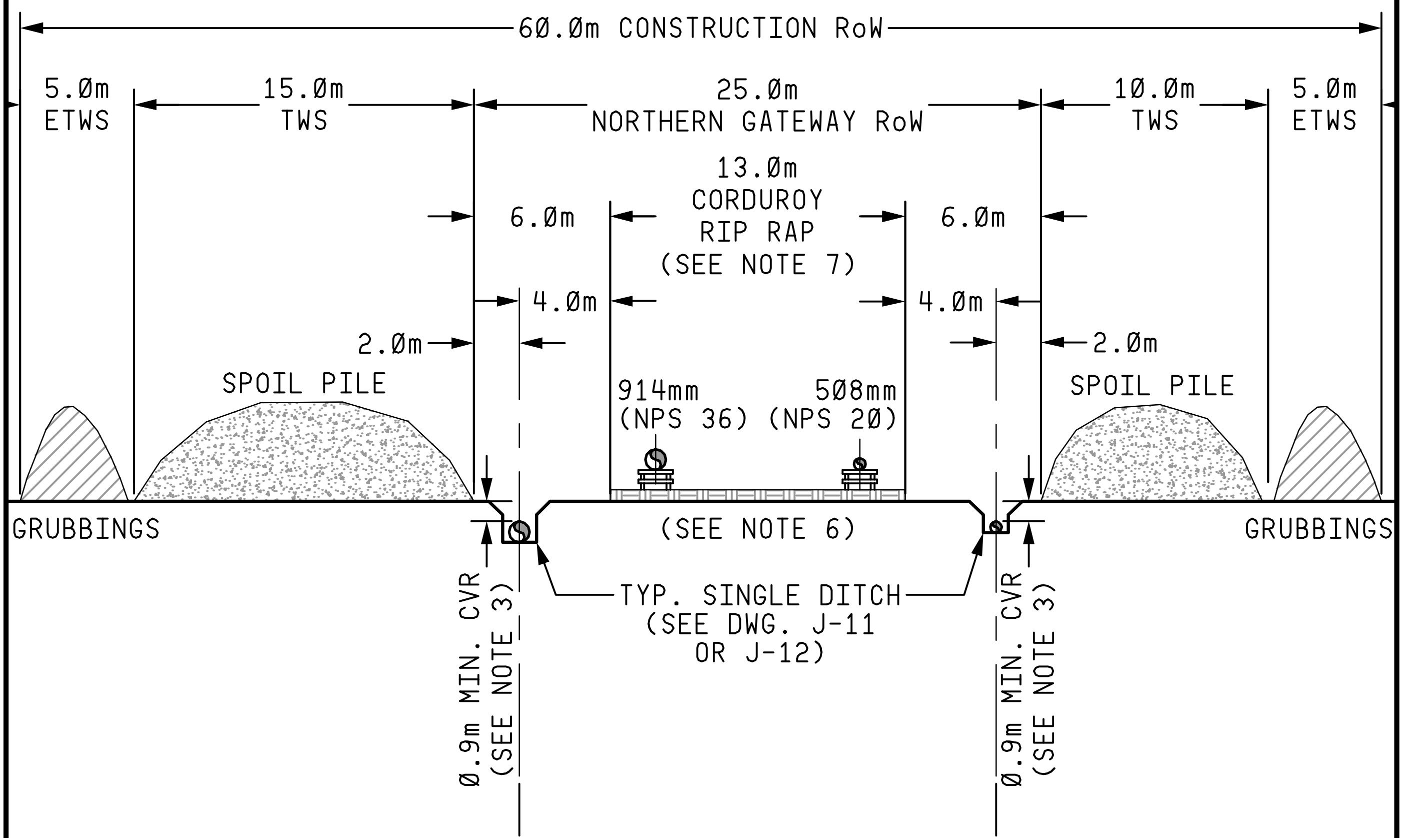
PHASE 2 INSTALL 508mm (NPS 20) PIPE



NOTES:

1. DITCH EXCAVATION SHALL BE IN ACCORDANCE WITH OH&S REGULATIONS.
2. STRIP TOPSOIL IN ACCORDANCE WITH ENBRIDGE SPECIFICATIONS.
3. MINIMUM COVER MEASURED FROM GRADE AFTER STRIPPING.
4. MAINTAIN 0.9m COVER OVER BUOYANCY CONTROL ELEMENTS AND OTHER APPURTENANCES MEASURED FROM GRADE AFTER STRIPPING.
5. ASSUME NORMAL BACKFILL.

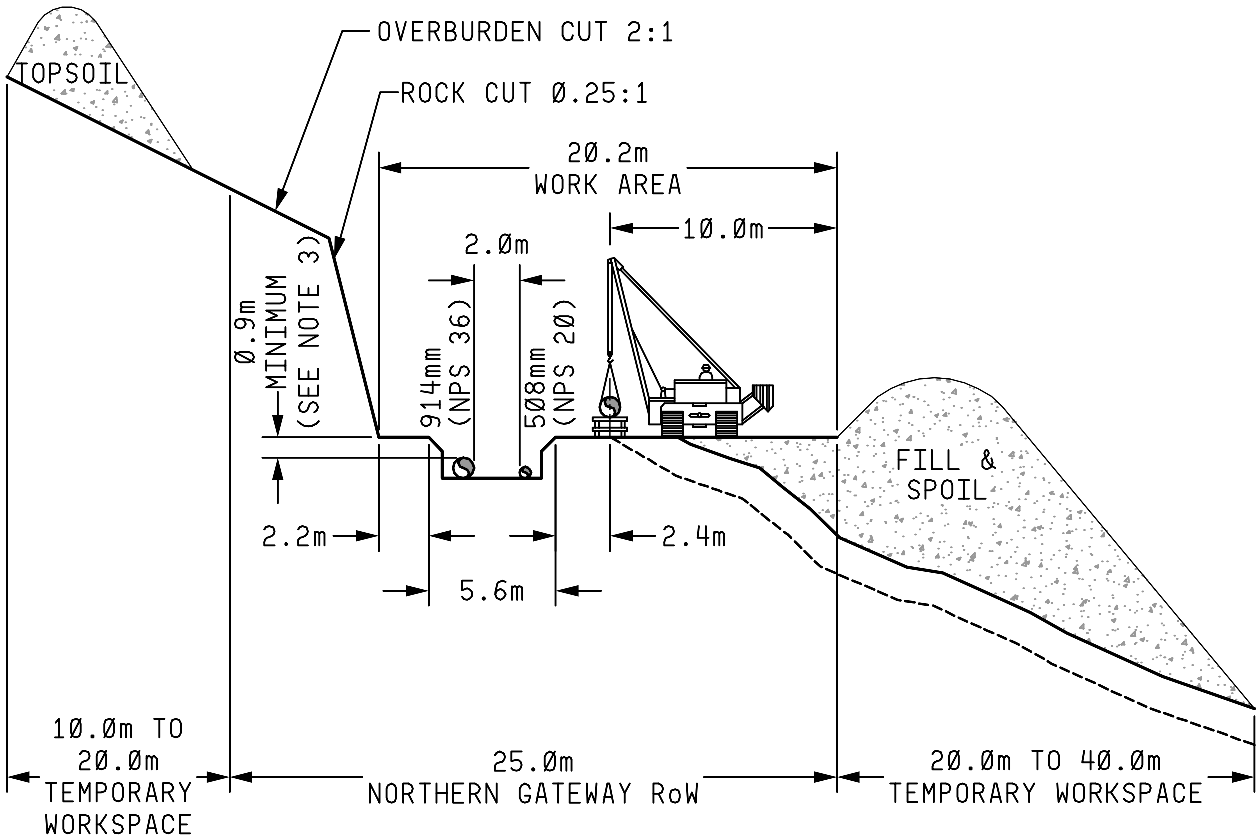
FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION C DATE 15 SEP 2009
	RoW CONFIGURATION WORK SIDE ADJACENT TO ALLIANCE PIPELINE	FIGURE NO. J-5



NOTES:

1. DITCH EXCAVATION SHALL BE IN ACCORDANCE WITH OH&S REGULATIONS.
2. STRIP TOPSOIL IN ACCORDANCE WITH ENBRIDGE SPECIFICATIONS.
3. MINIMUM COVER MEASURED FROM GRADE AFTER STRIPPING.
4. MAINTAIN 0.9m COVER OVER BUOYANCY CONTROL ELEMENTS AND OTHER APPURTENANCES MEASURED FROM GRADE AFTER STRIPPING.
5. ASSUME NORMAL BACKFILL.
6. 914mm INSTALLED FIRST AND TRENCH BACKFILLED. TURN AROUND TO INSTALL 508mm AND BACKFILL TRENCH.
7. ASSUME THE 13.0m WIDE RIP RAP WILL BE DIVIDED 4.0m FOR PIPE LAY DOWN AND 9.0m FOR WORK SIDE OR TRAVEL LANE, ALTERNATING AS DIRECTION OF LAY CHANGES.

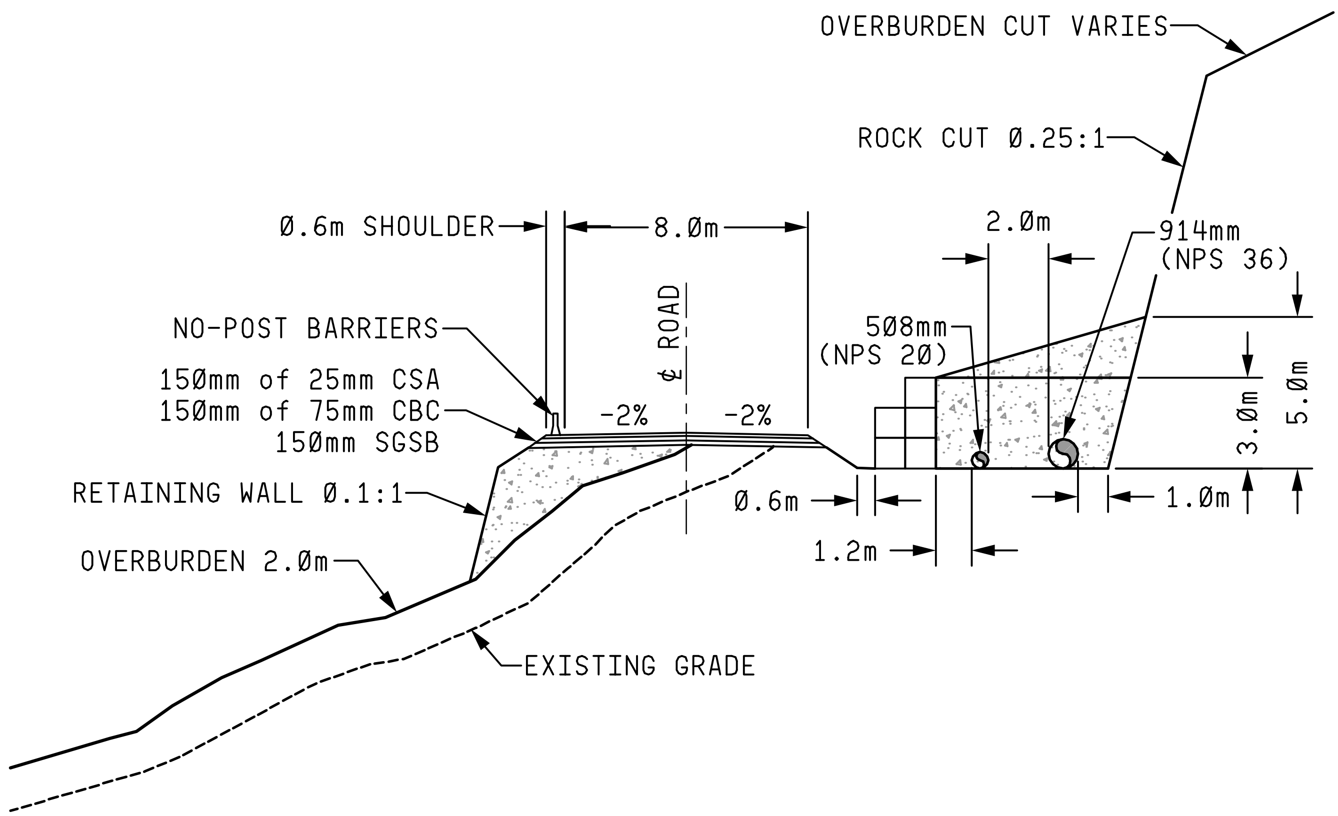
FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION C DATE 15 SEP 2009
	RIGHT OF WAY CONFIGURATION SUMMER WETLAND (MUSKEG) CONSTRUCTION	FIGURE NO. J–6



NOTES:

1. DITCH EXCAVATION SHALL BE IN ACCORDANCE WITH OH&S REGULATIONS.
2. STRIP TOPSOIL IN ACCORDANCE WITH ENBRIDGE SPECIFICATIONS.
3. MINIMUM COVER MEASURED FROM GRADE AFTER STRIPPING.
4. MAINTAIN Ø.9m COVER OVER BUOYANCY CONTROL ELEMENTS AND OTHER APPURTENANCES MEASURED FROM GRADE AFTER STRIPPING. MINIMUM COVER REQUIREMENT IS REDUCED TO Ø.6m THROUGH SOLID ROCK.
5. PIPE WILL BE WELDED THEN LOWERED-IN ONE SECTION AT A TIME.
6. TEMPORARY WORKSPACE WILL VARY WITH THE LAY OF THE LAND (THE CUT MATERIAL MAY ALSO BE PUSHED UP AND DOWN THE RoW AND STORED AS THE CONTOURS MAY ALLOW).
7. THE LAY DIRECTION MAY BE REVERSED TO ACCOMMODATE THE TRENCH CUT INTO THE HILL SIDE.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION B DATE 28 MAY 2009
	RIGHT OF WAY CONFIGURATION EXTREME SIDE SLOPE ROCK CUT	FIGURE NO. J–7

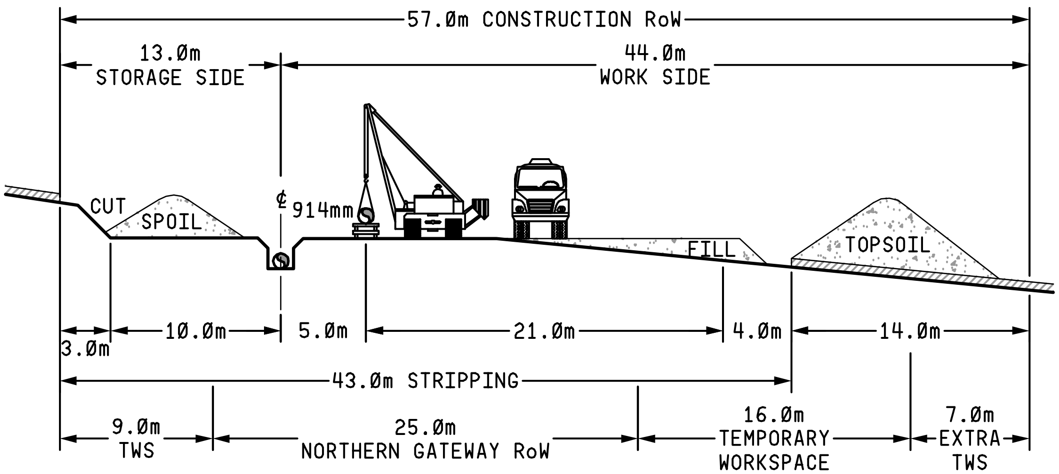


NOTES:

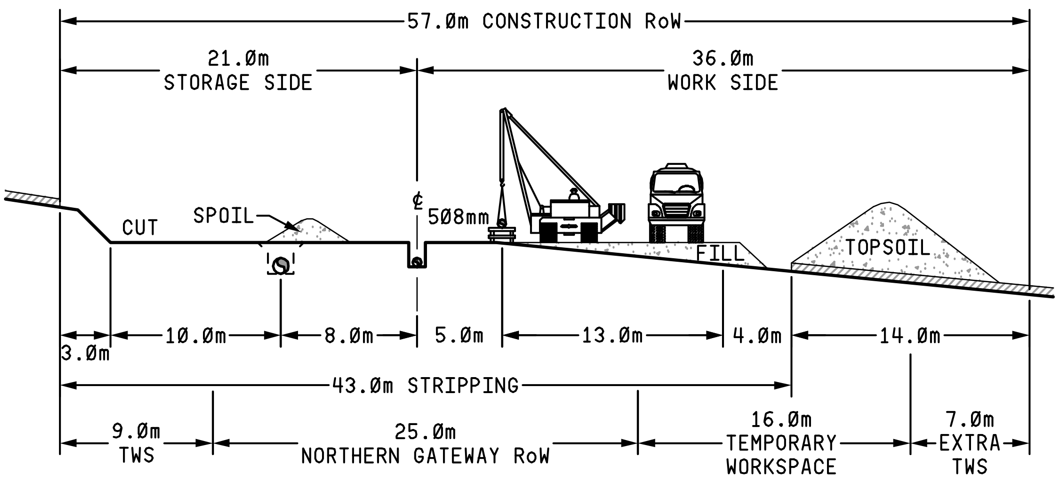
1. DITCH EXCAVATION SHALL BE IN ACCORDANCE WITH OH&S REGULATIONS.
2. STRIP TOPSOIL IN ACCORDANCE WITH ENBRIDGE SPECIFICATIONS.
3. PIPE LAID ON UNDISTURBED GROUND OR PADDING.
4. RETAINING WALL TO BE ENGINEERED DESIGN.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION B DATE 28 MAY 2009
	RIGHT OF WAY CONFIGURATION EXTREME SIDESLOPE ROCK CUT WITH PERMANENT ROAD	FIGURE NO. J-8

PHASE 1 INSTALL 914mm (NPS 36) PIPE EAST TO WEST



PHASE 2 INSTALL 508mm (NPS 20) PIPE EAST TO WEST

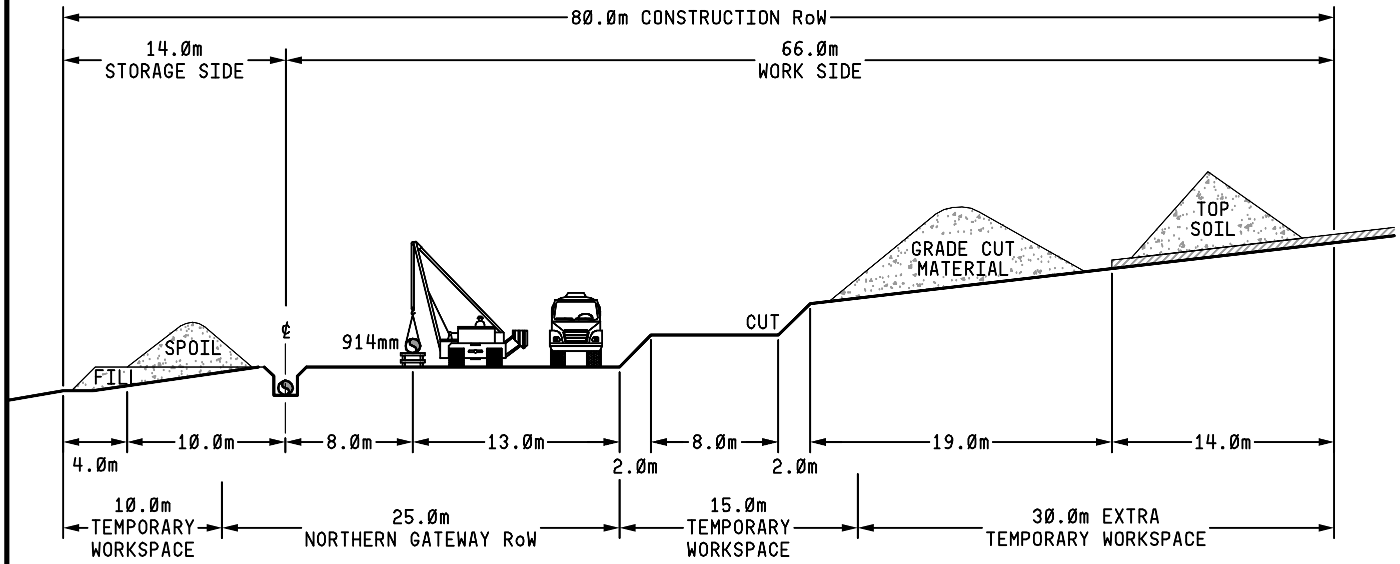


NOTES:

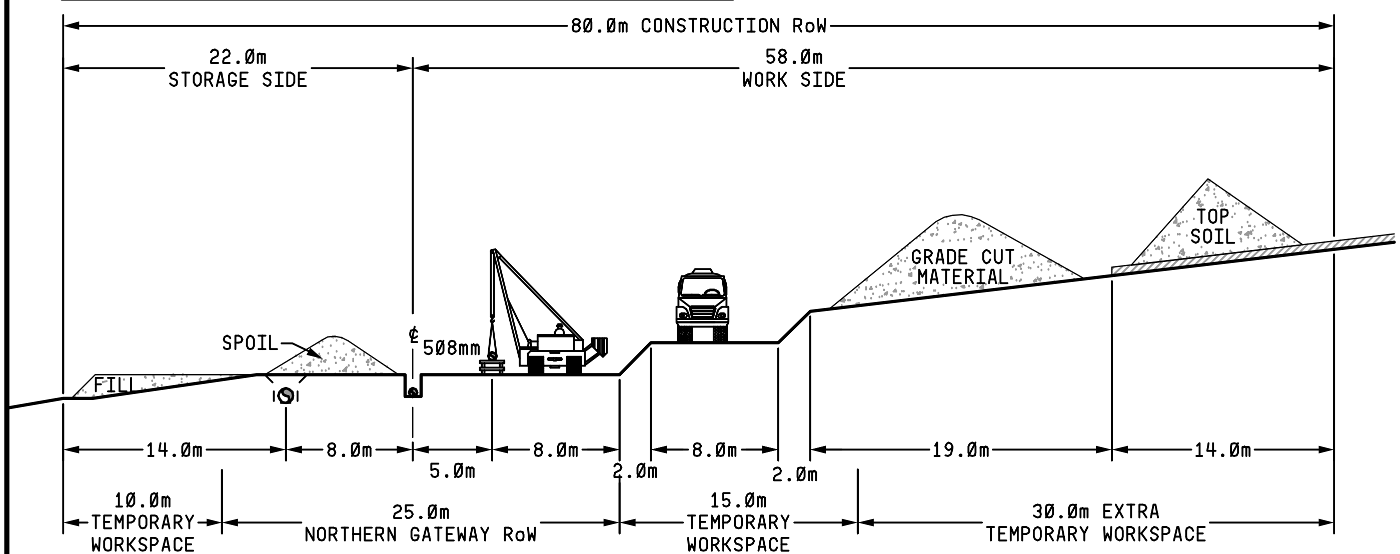
1. DITCH EXCAVATION SHALL BE IN ACCORDANCE WITH OH&S REGULATIONS.
2. STRIP TOPSOIL IN ACCORDANCE WITH ENBRIDGE SPECIFICATIONS.
3. MINIMUM COVER MEASURED FROM GRADE AFTER STRIPPING.
4. MAINTAIN 0.9m COVER OVER BUOYANCY CONTROL ELEMENTS AND OTHER APPURTENANCES MEASURED FROM GRADE AFTER STRIPPING. MINIMUM COVER REQUIREMENT IS REDUCED TO 0.6m THROUGH SOLID ROCK.
5. ASSUME NORMAL BACKFILL.
6. 914mm INSTALLED FIRST AND TRENCH BACKFILLED. SPOIL FROM 508mm TRENCH PLACED OVER 914mm.
7. WINTER CONSTRUCTION MAY REQUIRE ADDITIONAL EXTRA TEMPORARY WORKSPACE FOR STORAGE OF SNOW.
8. SEE DRAWINGS J-11 OR J-12 FOR TYPICAL DITCH DESIGN.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION D DATE 15 SEP 2009
	RIGHT OF WAY CONFIGURATION – SUMMER–10% SIDEHILL–WORKSIDE FILL	FIGURE NO. J–9

PHASE 1 INSTALL 914mm (NPS 36) PIPE EAST TO WEST



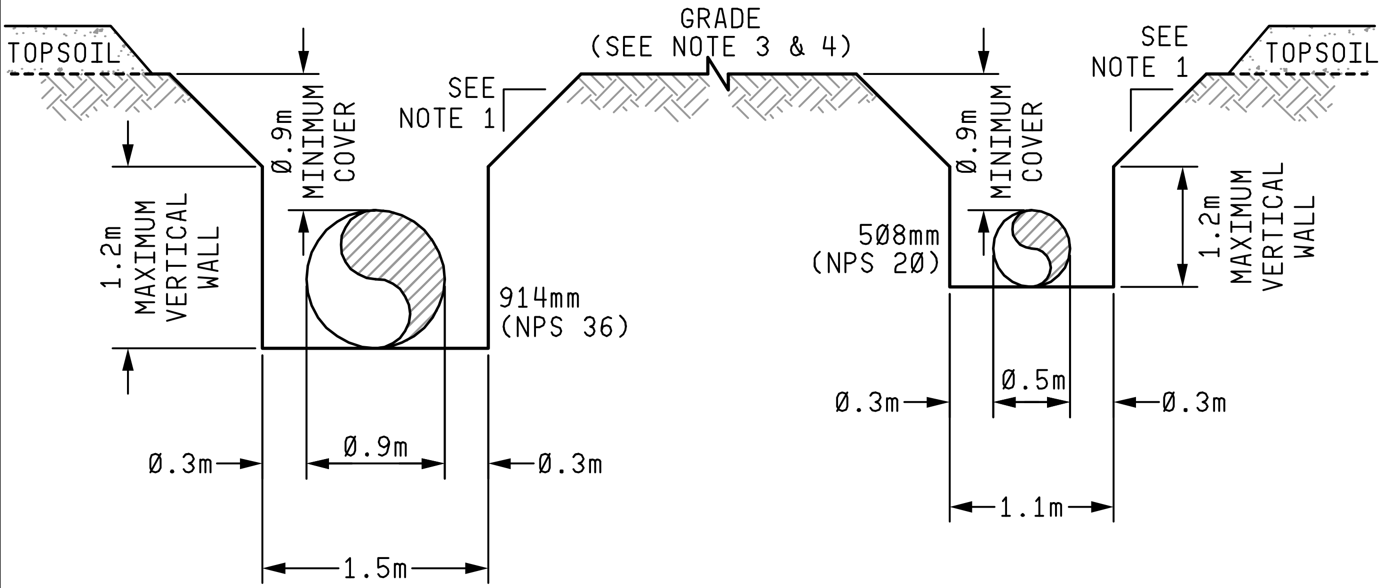
PHASE 2 INSTALL 508mm (NPS 20) PIPE EAST TO WEST



NOTES:

1. DITCH EXCAVATION SHALL BE IN ACCORDANCE WITH OH&S REGULATIONS.
2. STRIP TOPSOIL IN ACCORDANCE WITH ENBRIDGE SPECIFICATIONS.
3. MINIMUM COVER MEASURED FROM GRADE AFTER STRIPPING.
4. MAINTAIN 0.9m COVER OVER BUOYANCY CONTROL ELEMENTS AND OTHER APPURTENANCES MEASURED FROM GRADE AFTER STRIPPING. MINIMUM COVER REQUIREMENT IS REDUCED TO 0.6m THROUGH SOLID ROCK.
5. ASSUME NORMAL BACKFILL.
6. 914mm INSTALLED FIRST AND TRENCH BACKFILLED. SPOIL FROM 508mm TRENCH PLACED OVER 914mm.
7. WINTER CONSTRUCTION MAY REQUIRE ADDITIONAL EXTRA TEMPORARY WORKSPACE FOR STORAGE OF SNOW.
8. SEE DRAWINGS J-11 OR J-12 FOR TYPICAL DITCH DESIGN.

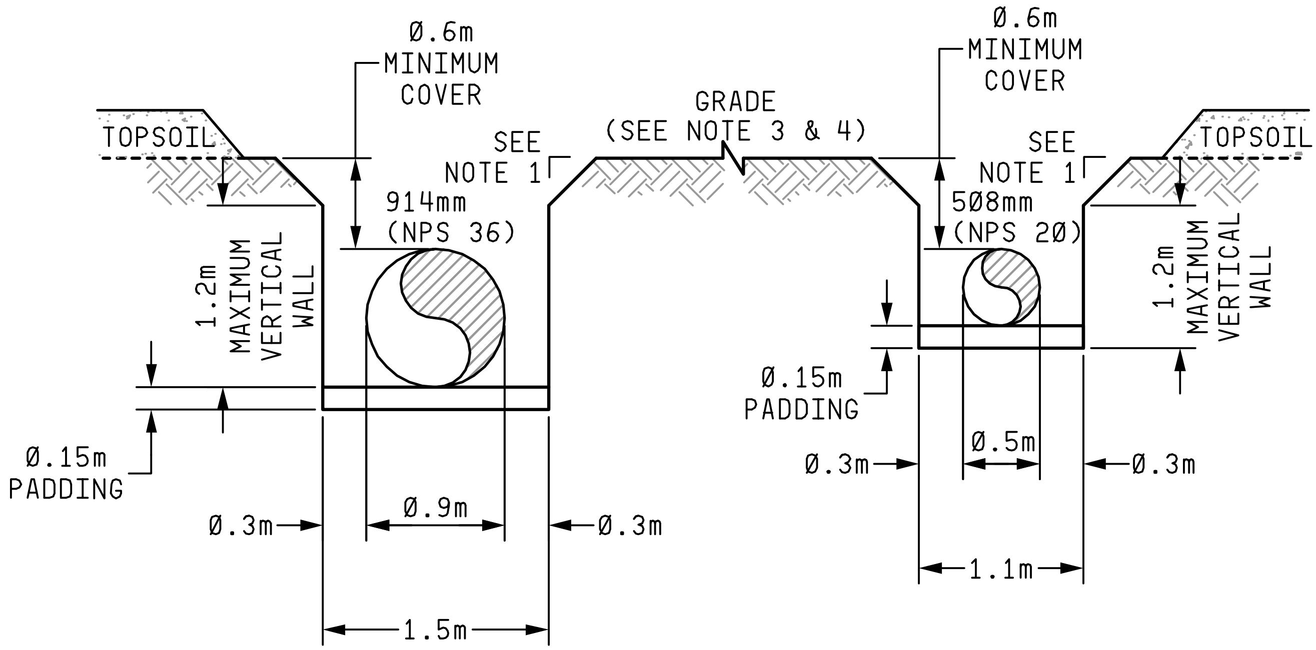
FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION D DATE 15 SEP 2009
	RIGHT OF WAY CONFIGURATION – SUMMER–10% SIDEHILL–WORKSIDE CUT	FIGURE NO. J–10



NOTES:

1. DITCH EXCAVATION SHALL BE IN ACCORDANCE WITH OH&S REGULATIONS BASED ON SOIL CONDITIONS.
2. STRIP TOPSOIL IN ACCORDANCE WITH ENBRIDGE SPECIFICATIONS.
3. MINIMUM COVER MEASURED FROM GRADE AFTER STRIPPING.
4. MAINTAIN Ø.9m COVER OVER BUOYANCY CONTROL ELEMENTS AND OTHER APPURTENANCES MEASURED FROM GRADE AFTER STRIPPING.

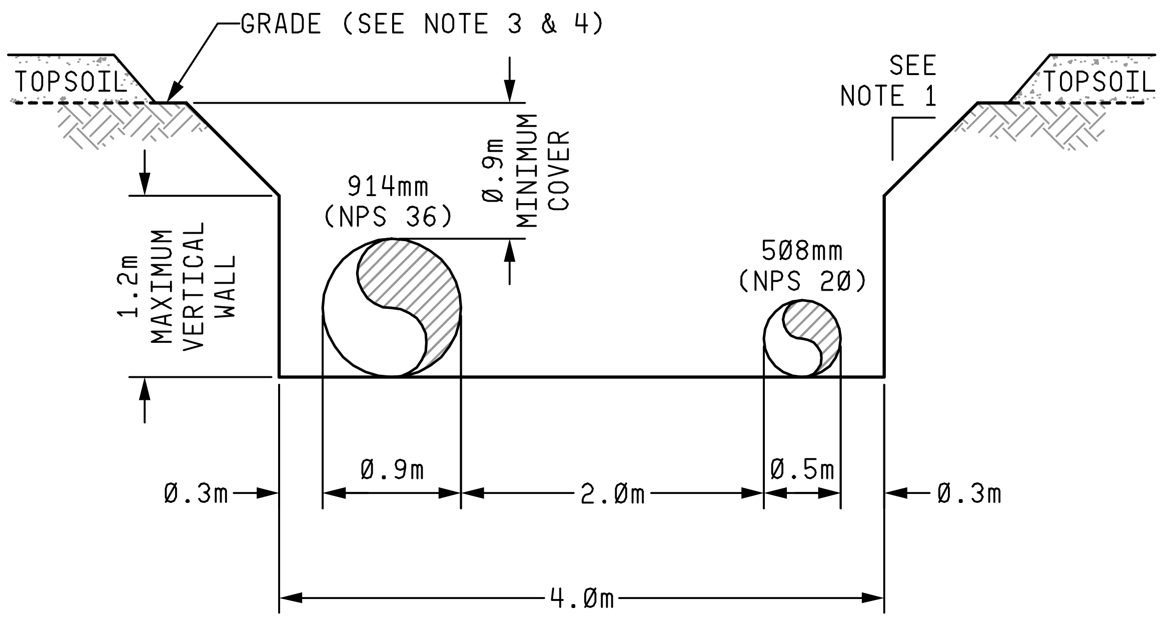
FIGURE ID		SCALE	N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION	C
		DATE	28 MAY 2009
	DITCH DESIGN SINGLE PIPE(914mm/508mm)–NORMAL TRENCH	FIGURE NO.	J–11



NOTES:

1. DITCH EXCAVATION SHALL BE IN ACCORDANCE WITH OH&S REGULATIONS BASED ON SOIL CONDITIONS.
2. STRIP TOPSOIL IN ACCORDANCE WITH ENBRIDGE SPECIFICATIONS.
3. MINIMUM COVER MEASURED FROM GRADE AFTER STRIPPING.
4. MAINTAIN Ø.6m COVER OVER BUOYANCY CONTROL ELEMENTS AND OTHER APPURTENANCES MEASURED FROM GRADE AFTER STRIPPING.

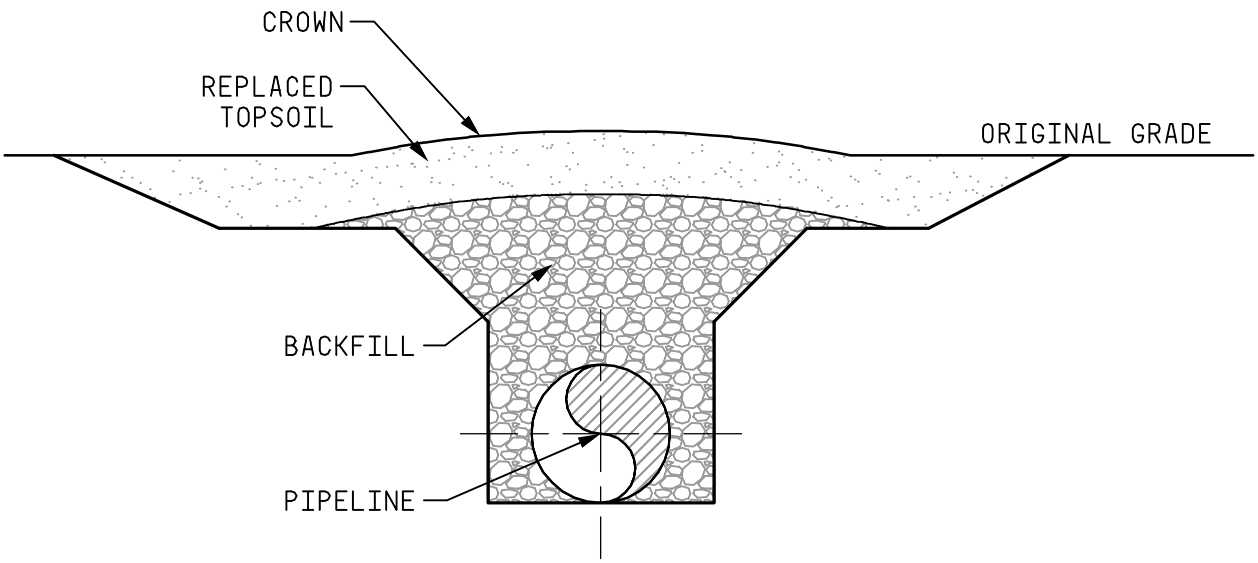
FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION C DATE 28 MAY 2009
	DITCH DESIGN SINGLE PIPE(914mm/508mm)–ROCK TRENCH	FIGURE NO. J–12



NOTES:

1. DITCH EXCAVATION SHALL BE IN ACCORDANCE WITH OH&S REGULATIONS BASED ON SOIL CONDITIONS.
2. STRIP TOPSOIL IN ACCORDANCE WITH ENBRIDGE SPECIFICATIONS.
3. MINIMUM COVER MEASURED FROM GRADE AFTER STRIPPING.
4. MAINTAIN Ø.9m COVER OVER BUOYANCY CONTROL ELEMENTS AND OTHER APPURTENANCES MEASURED FROM GRADE AFTER STRIPPING. MINIMUM COVER REQUIREMENT IS REDUCED TO Ø.6m THROUGH SOLID ROCK.
5. IN LOCATIONS WHERE BOTH LINES ARE PROTECTED WITH A CONCRETE COATING, THE CLEARANCE BETWEEN THE LINES MAY BE REDUCED OR ELIMINATED.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION C DATE 28 MAY 2009
	DITCH DESIGN DUAL PIPE—NORMAL TRENCH	FIGURE NO. J—13



NOTES:

1. CROWN THE TRENCH TO COMPENSATE FOR SETTLEMENT. THE HEIGHT OF THE CROWN WILL DEPEND UPON LAND USE, THE DEGREE OF COMPACTION ACHIEVED, AND SOIL TEMPERATURE. TYPICAL VALUES FOR CROWNING OF REPRESENTATIVE SOIL TYPES ARE PRESENTED BELOW.

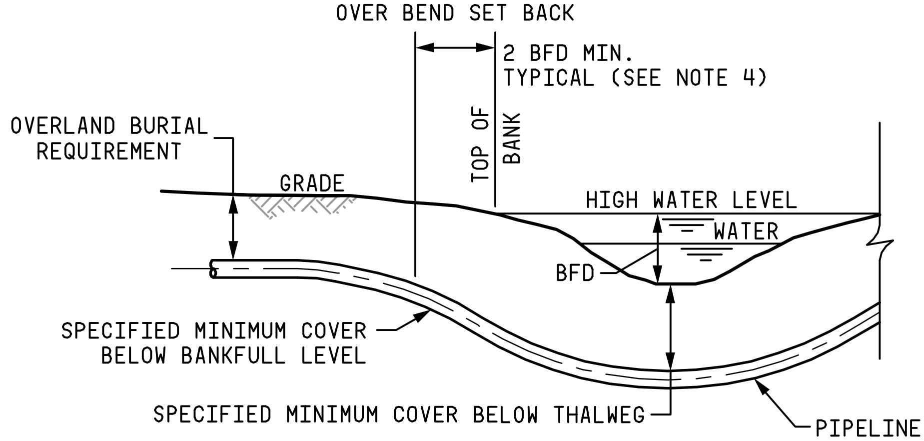
$R = A \times D$ WHERE R = HEIGHT OF CROWN
A = CROWN ALLOWANCE
D = DEPTH OF TRENCH

TYPE OF BACKFILL	TYPICAL CROWN ALLOWANCE (A)
BLASTED ROCK	.00 - .05
SAND AND GRAVEL	.05 - .10
SAND	.08 - .15
SILTY SAND	.10 - .15
SILT	.10 - .20
CLAY	.10 - .25
ORGANIC (MUSKEG)	.50 - 1.00

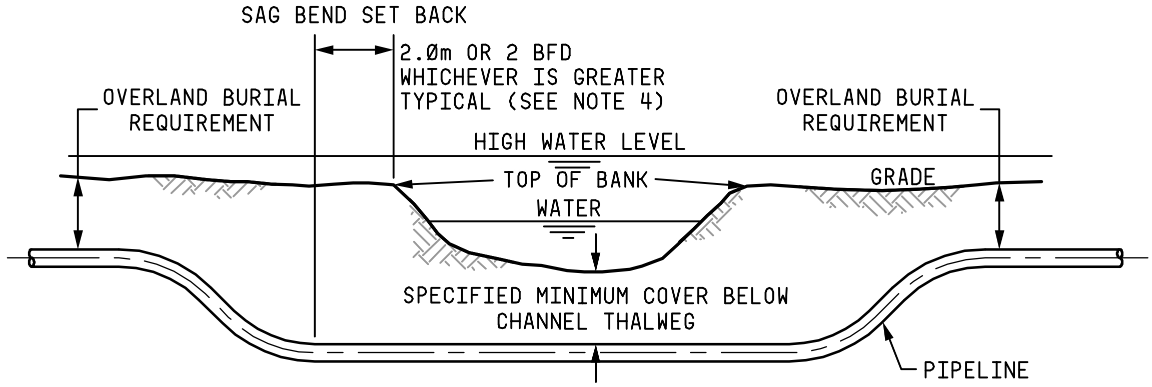
2. LEAVE GAPS IN CROWN AT ALL DRAINAGE COURSES AND AT TRENCH BREAKERS TO ALLOW FOR SURFACE RUN-OFF.
3. FEATHER OUT EXCESS SPOIL.
4. REPLACE TOPSOIL EVENLY.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION C DATE 28 MAY 2009
	RIGHT OF WAY AFTER BACKFILL SINGLE TRENCH	FIGURE NO. J-14

TYPICAL SINGLE SAG CROSSING



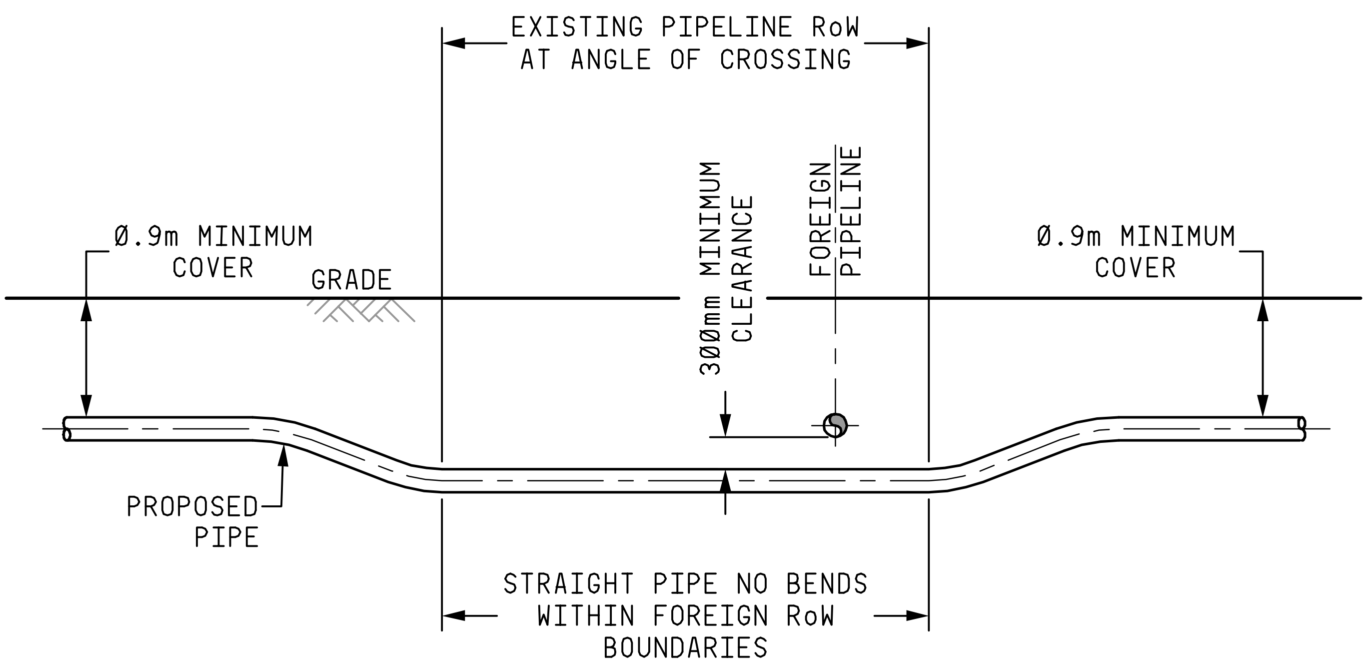
TYPICAL DOUBLE SAG CROSSING



NOTES:

1. USE SINGLE SAG CROSSING ON NARROW STREAMS WHERE IT IS POSSIBLE TO MAINTAIN MINIMUM COVER AND WHERE THERE IS NO EVIDENCE OF CAVING BANKS, SCOUR OR SHIFTING BOTTOM.
2. NORMALLY USE DOUBLE SAG CROSSING WHERE WIDTH PROHIBITS USE OF SINGLE SAG OR WHERE BANKS ARE WASHING AND PIPELINE MUST BE CARRIED INTO THE BANKS TO MAINTAIN MINIMUM COVER.
3. DISTURBED BANK AREAS SHALL BE RESTORED BY GRADING TO NO STEEPER THAN 3H:1V AND REVEGETATING AS SOON AS POSSIBLE FOLLOWING CONSTRUCTION. TRANSITIONS TO UPSTREAM AND DOWNSTREAM BANKS SHALL BE SMOOTH AND GRADUAL.
4. BFD (BANK FULL DEPTH) IS THE VERTICAL DISTANCE FROM THE LOWEST BANK TO THE LOWEST BED ELEVATION.
5. BUOYANCY CONTROL TO BE INSTALLED AS REQUIRED.

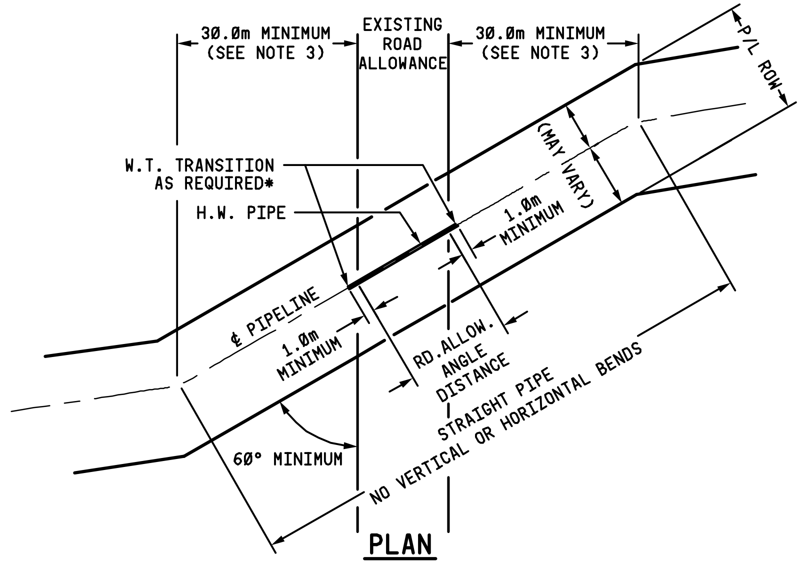
FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION B DATE 28 MAY 2009
	TYPICAL WATERCOURSE CROSSING DESIGN	FIGURE NO. J–15



NOTES:

1. FOREIGN PIPELINE LOCATIONS AND DEPTHS TO BE DETERMINED BY ELECTRONIC MEANS IN ADVANCE OF PIPELINE OPERATION AND CONFIRMED BY CAREFULLY EXPOSING BY HAND DIGGING OR "HYDRO VAC".
2. THE OWNER OF FOREIGN PIPELINE(S) SHALL BE NOTIFIED AT LEAST 72 HOURS IN ADVANCE OF EXCAVATION OF CROSSING, OR AS REQUIRED BY THE CROSSING LINE LIST. THE FOREIGN PIPELINE OWNER OR HIS REPRESENTATIVE SHALL BE PRESENT ON SITE WHEN THE CROSSING OPERATION TAKES PLACE UNLESS OTHERWISE APPROVED IN WRITING BY THE FOREIGN PIPELINE OWNER.
3. PROPOSED PIPELINE MAY ONLY CROSS ABOVE FOREIGN PIPELINE(S) WHERE REQUESTED BY OR APPROVED BY THE FOREIGN PIPELINE OWNER IN WRITING, PROVIDED THAT MINIMUM CLEARANCE AND COVER IS MAINTAINED. THE FOREIGN PIPELINE OWNER IN WRITING, PROVIDED THAT MINIMUM CLEARANCE AND COVER IS MAINTAINED.
4. CROSSING SHALL BE CONSTRUCTED IN ACCORDANCE WITH CAN/CSA Z662-Ø7 OIL AND GAS PIPELINE STANDARD AND NEB OPR 99 REGULATIONS.
5. PLASTIC OR COMPOSITE PIPELINES SHALL BE SUPPORTED AS REQUESTED BY THE FOREIGN PIPELINE OWNER. IF THE FOREIGN LINE OWNER HAS NO SPECIFIC REQUIRMENTS, ANGLE IRON 75mm x 75mm x 6mm SHALL BE USED.
6. ALL BACKFILL WITHIN 2.Øm OF A FOREIGN PIPELINE CROSSING TO BE DEPOSITED IN 15Ømm LIFTS AND COMPACTED TO 85% STANDARD PROCTOR DENSITY.
7. CATHODIC PROTECTION TEST POINTS WILL BE INSTALLED WHERE CALLED FOR BY THE FOREIGN PIPELINE OWNER OR AS SPECIFIED BY ENBRIDGE.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION C DATE 28 MAY 2009
	TYPICAL PIPELINE CROSSING DESIGN	FIGURE NO. J–16



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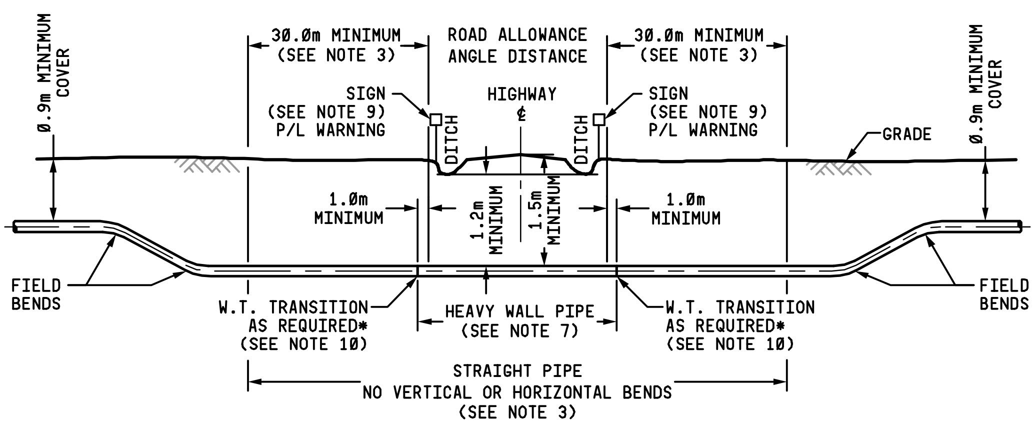


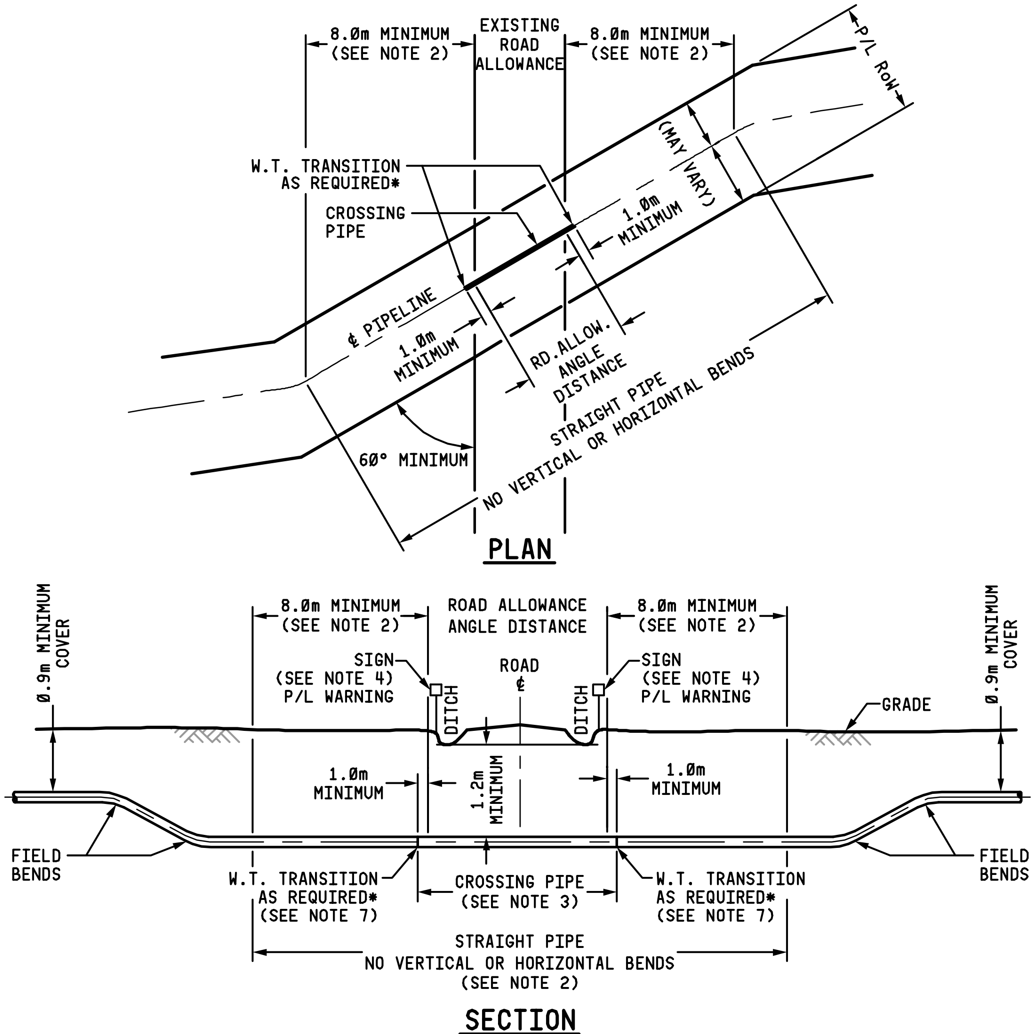
SECTION

PIPELINE DATA	NPS 36		NPS 20		PIPE SPECIFICATION	COATING	CATH. PROT.
	O.D.(mm)	W.T.(mm)	O.D.(mm)	W.T.(mm)			
LINE PIPE	914.4	VARIES	508.0	VARIES	CSA Z245.1 GR. 483 CAT. I	FBE	YES
H.W. PIPE	914.4	VARIES	508.0	VARIES	CSA Z245.1 GR. 483 CAT. I	FBE WITH ABRASION OVERCOAT	YES

NOTES:

1. THE ROAD BED AND DITCHES AT THE PIPELINE CROSSING SHALL BE RESTORED TO THE APPROVAL OF THE AUTHORITIES HAVING JURISDICTION.
2. CORROSION CONTROL SHALL CONSIST OF FUSION BOND EPOXY COATING AND CATHODIC PROTECTION.
3. PRIMARY OR SECONDARY HIGHWAY CROSSINGS SHALL HAVE NO VERTICAL OR HORIZONTAL BEND WITHIN THE ROAD ALLOWANCE OR A 30.0m PERPENDICULAR DISTANCE FROM ROAD ALLOWANCE OR AS APPROVED BY THE AUTHORITIES HAVING JURISDICTION.
4. PIPELINE CONSTRUCTION SHALL BE CONSTRUCTED IN ACCORDANCE WITH CSA Z662-07 OIL AND GAS PIPELINE STANDARD AND THE NEB OPR 99 REGULATIONS.
5. THE PIPE COATING SHALL BE INSPECTED PRIOR TO INSTALLATION AND DAMAGED AREAS REPAIRED.
6. NO OPEN EXCAVATION SHALL BE CLOSER THAN 3.6m FROM THE SHOULDER OF THE ROAD WHEN USING BORING TECHNIQUES.
7. REFER TO CONSTRUCTION ALIGNMENT SHEET FOR HEAVY WALL PIPE W.T. AND LENGTH AT EACH CROSSING.
8. CROSSING SHALL BE CONSTRUCTED USING TRENCHLESS METHOD.
9. REFER TO DWG. FOR TYPICAL WARNING SIGN DETAILS.
10. REFER TO DWG. FOR TRANSITION DETAILS.
11. REFER TO CONSTRUCTION ALIGNMENT SHEETS FOR LINE PIPE W.T.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION C DATE 28 MAY 2009
	TYPICAL PRIMARY ROAD CROSSING DESIGN	FIGURE NO. J-17

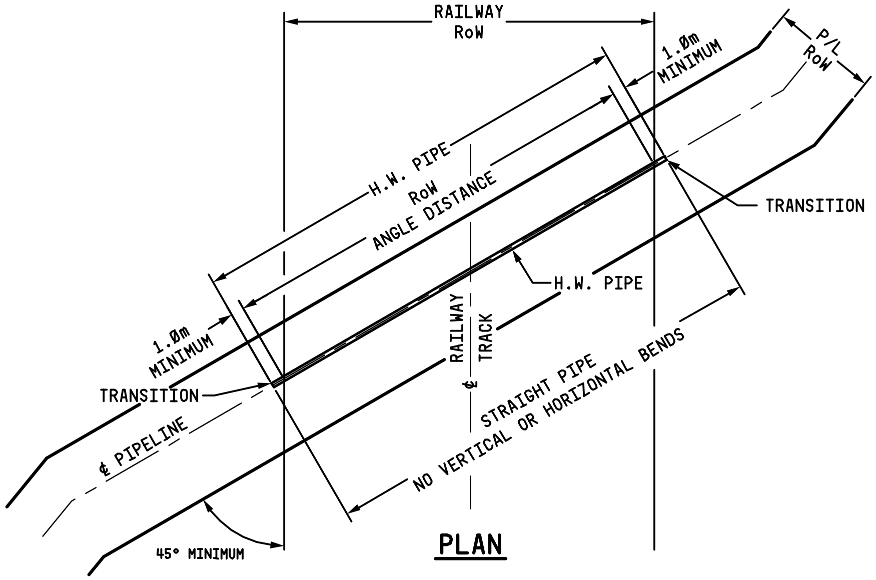


PIPELINE DATA	NPS 36		NPS 20		PIPE SPECIFICATION	COATING	CATH. PROT.
	O.D.(mm)	W.T.(mm)	O.D.(mm)	W.T.(mm)			
LINE PIPE	914.4	VARIES	508.0	VARIES	CSA Z245.1 GR. 483 CAT. I	FBE	YES
H.W. PIPE	914.4	VARIES	508.0	VARIES	CSA Z245.1 GR. 483 CAT. I	FBE WITH ABRASION OVERCOAT	YES

NOTES:

1. CROSSING SHALL BE CONSTRUCTED USING BORE METHOD OR OPEN CUT AS PER CONTRACT.
2. THE CONSTRUCTED PIPELINE SHALL BE STRAIGHT WITH NO VERTICAL OR HORIZONTAL BENDS ACROSS THE ROAD ALLOWANCE AND WITHIN A 8.0m PERPENDICULAR DISTANCE FROM ROAD ALLOWANCE BOUNDARY OR AS APPROVED BY AUTHORITIES HAVING JURISDICTION. LENGTH OF STRAIGHT PIPE AS A DISTANCE FROM ROAD BOUNDARY AND ANGLE OF CROSSING WILL VARY WITH SITE PLAN AND THE IMPACT OF ADJACENT RoW's AND PIPELINES ON PROPOSED PIPELINE.
3. REFER TO CONSTRUCTION ALIGNMENT SHEET FOR HEAVY WALL PIPE W.T. AND LENGTH AT EACH CROSSING.
4. REFER TO DWG. FOR TYPICAL WARNING SIGN DETAILS.
5. CROSSING SHALL BE CONSTRUCTED IN ACCORDANCE WITH CSA Z662-07 OIL AND GAS PIPELINE STANDARD AND NEB OPR 99 REGULATIONS.
6. ALL MUNICIPAL/COUNTY (GRID) ROAD CROSSINGS SHALL BE MADE IN ACCORDANCE WITH ALL REQUIREMENTS OF THE PROVINCIAL AUTHORITY AND/OR THE MUNICIPALITY HAVING JURISDICTION.
7. REFER TO DWG. FOR TRANSITION DETAILS.
8. REFER TO CONSTRUCTION ALIGNMENT SHEETS FOR LINE PIPE W.T.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION C DATE 28 MAY 2009
	TYPICAL SECONDARY ROAD CROSSING DESIGN	FIGURE NO. J-18



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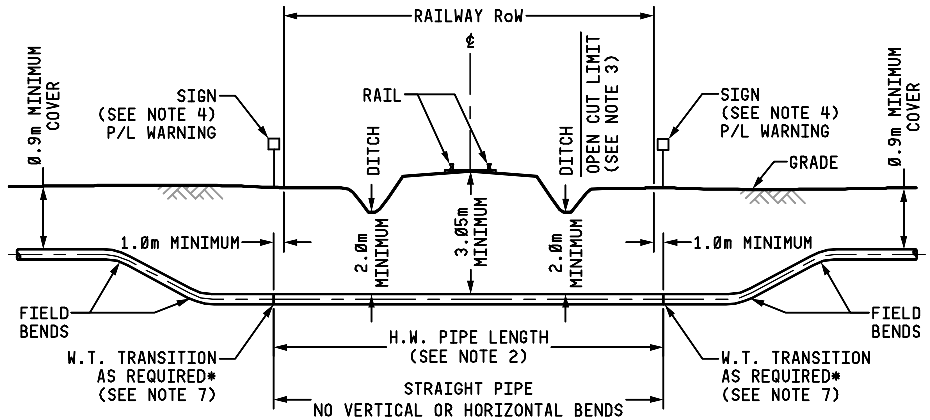

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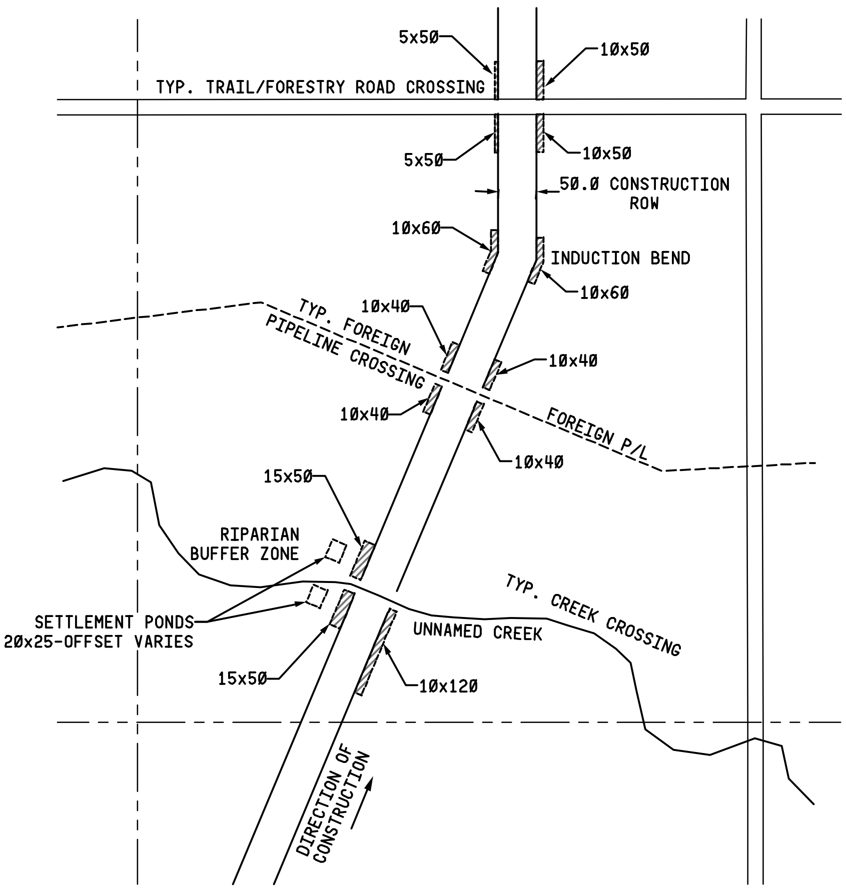
PIPELINE DATA	NPS 36		NPS 20		PIPE SPECIFICATION	COATING	CATH. PROT.
	O.D.(mm)	W.T.(mm)	O.D.(mm)	W.T.(mm)			
LINE PIPE	914.4	VARIES	508.0	VARIES	CSA Z245.1 GR. 483 CAT. I	FBE	YES
H.W. PIPE	914.4	VARIES	508.0	VARIES	CSA Z245.1 GR. 483 CAT. I	FBE WITH ABRASION OVERCOAT	YES

NOTES:

1. REFER TO DWG. FOR WARNING SIGN DETAILS.
2. REFER TO "SITE SPECIFIC" CROSSING DRAWING OR CONSTRUCTION ALIGNMENT SHEET FOR LENGTH OF H.W. PIPE REQUIRED.
3. ALL CROSSINGS SHALL BE TRENCHLESS. OPEN CUTTING TO BORE FACE SHALL BE IN ACCORDANCE WITH CONSTRUCTION CONTRACT.
4. CONSTRUCTION TO CONFORM TO CSA Z662-07 OIL AND GAS PIPELINE STANDARDS NEB OPR 99 REGULATIONS AND TRANSPORT CANADA (TC) STANDARD E-10.
5. EXTERIOR COATING OF CARRIER PIPE SHALL BE INSPECTED IMMEDIATELY PRIOR TO INSTALLATION AND ALL DAMAGED AREAS REPAIRED.
6. CORROSION CONTROL WILL BE ACHIEVED THROUGH THE USE OF FBE COATING AND CATHODIC PROTECTION.
7. VOIDS AROUND PIPE WITHIN BORE GREATER THAN 25mm SHALL BE FILLED BY PRESSURE GROUTING.
8. REFER TO DWG. FOR W.T. TRANSITION DETAILS.
9. REFER TO CONSTRUCTION ALIGNMENT SHEETS FOR LINE PIPE W.T.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION B DATE 28 MAY 2009
	TYPICAL RAILWAY CROSSING DESIGN	FIGURE NO. J-19



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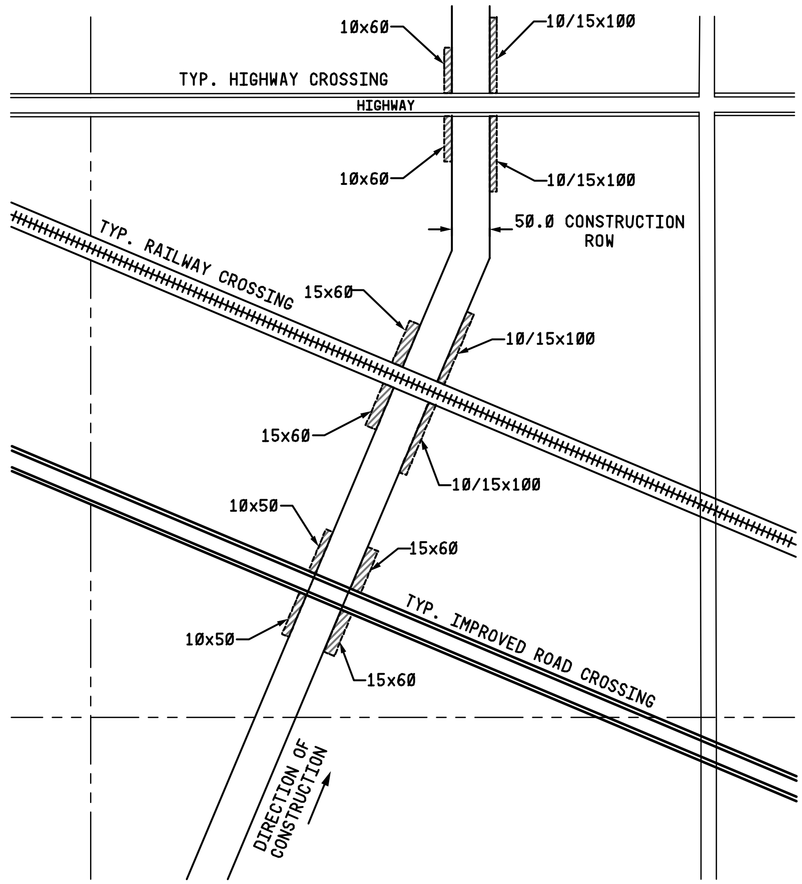

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NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS SHOWN OTHERWISE.
2. DIMENSIONS ARE APPLICABLE FOR CROSSING INTERSECTING RoW AT OR NEAR 90°. LESSER ANGLES WILL INCREASE LENGTHS.
3. WHERE RoW IS ADJACENT TO AN EXISTING RoW MOST OF THE ETWS WILL BE ON THE ONE SIDE OPPOSITE THE EXISTING LINE.

FIGURE ID		SCALE N.T.S.
PREPARED FOR ENBRIDGE NORTHERN GATEWAY PIPELINES	ENBRIDGE NORTHERN GATEWAY PROJECT	REVISION D DATE 28 AUG 2009
	TYPICAL EXTRA TEMPORARY WORKSPACE FOR CROSSINGS	FIGURE NO. J-20